



**IBM** Federal Systems Division

AN INFORMATION SYSTEM  
FOR  
THE NATIONAL REGISTER

Districts, Sites, Buildings, Structures, and Objects  
Which are Significant in American History, Archeology,  
Architecture and Culture

PREPARED JOINTLY  
BY

Department of the Interior  
National Park Service  
Office of Archeology and Historic Preservation

AND

International Business Machines Corporation  
Federal Systems Division

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## Section 1

### INTRODUCTION

Our Nation's growth has accelerated to the point where many properties with historic, architectural, or archeological significance are endangered. Many of these properties are still privately owned and are not recognized by even local governments as having a place in our Nation's history and preservation programs.

The National Register, through Public Law 89-665, the National Historic Preservation Act, has been given the legal mandate to gather and effectively use information concerning these sites to ensure that proper consideration is given to them in federal, state, and other development programs.

More than 35 different federal agencies with licensing and construction or assistance programs which would possibly have need of consulting the National Register under provisions of Section 106 of the National Preservation Act have been identified. These agencies as well as state and local government groups and scholars everywhere have an increasing need for information concerning the location, description, and significance of these properties.

Through a planned program at the state level, an inventory of these properties will be made and those selected for inclusion in the National Register will be added to the data files maintained by the Office of Archeology and Historic Preservation of the National Park Service. This information can then be made available to those federal agencies, state and local government groups, or scholars who require it.

The estimated number of entries and the amount of data required for each submittal indicates that an automated data handling method is necessary. The computer in such a process would not only provide the speed of handling which is required, but it would provide the flexibility needed in the selection, ordering and

presentation of information from the data files. The information contained in these data files at the National Register can provide the necessary detail to:

- a. Provide the approximate geographic location of districts, sites, buildings, structures, and objects to be used in the determination of the effects of urban renewal, highway location, utility land acquisition, industrial and commercial development, and general urban growth on these historic properties.
- b. Retrieve information and produce reports concerning historic places included in the National Register for the purpose of Congressional reports; to answer Congressional or other agency inquiries; and to provide planning information for the Department of the Interior, the National Park Service, the States, and others.
- c. Select and order information for publication in the annual edition of the National Register of Historic Places.

The tasks listed above are (in themselves) more than the necessary justification for an automated processing of the collected data. In addition, the interests of other agencies make it mandatory that the data be quickly and easily accessible. Only an automated file system can assure adequate storage, retrieval and presentation for the volume of entries (over 100,000) anticipated.

This paper gives a general description of a system which could provide the support necessary to achieve the previously stated tasks. Emphasis is placed on the following three areas of consideration:

- a. Content and organization of the data collection forms to be used in establishing the National Register.
- b. The geographic description of sites and properties and the form of submittal and subsequent storage of this information.
- c. The possible software approaches which could be used to implement such a system.

## Section 2

### FILE CONTENT, ORGANIZATION AND DATA COLLECTION FORMS

The information which will be collected on the proposed forms should be broken down into three primary groupings:

a. District-Site Data

1. Name and encoded district or site description data
2. Significance rating
3. Geographic location.

b. Site Textual Description Data

A variable length description of the district or site to be used in the publication of the National Register.

c. Structures, Buildings, Objects, etc., Inventory Data

1. Name and encoded item description data
2. Significance rating
3. Description and explanatory remarks.

Descriptive information is required for each district or site which is nominated for inclusion in the National Register. This information will locate and provide the encoded descriptive data necessary for most retrieval requirements.

The variable-length textual data set provides a means of storing a description of the site for publication purposes. This description should be written by a qualified professional and should provide information suitable for use in the publication of the National Register. The information should be limited if possible to one or two paragraphs to reduce storage and final publication costs.

Structure, building, or object data may be submitted for each item of historic, architectural, archeological, or cultural significance at a particular

site or in the district. This provides an inventory of those significant items on the site which should be considered in any evaluation of the total site status.

Three forms are proposed for nominating a district or site and the buildings, structures, or objects associated with it. They include:

- a. Inventory Nomination Form. This form is submitted for each district, site, building, structure or object being nominated for inclusion in the National Register. Information such as ownership and property status, accessibility to the public, present use, location data, physical description, and historical significance data is submitted using this form.

For each submitted district or site which is selected for inclusion in the National Register, a master record would be established in the data base. The site within a district is then associated or linked to the district data through district-site number encoding assigned by the National Register people.

Each significant building, structure or object found on a site will also be submitted using this form. A detailed record will be established in the data base for each inventoried item selected for inclusion in the National Register. These items are associated or linked to the master site records established for each nomination. Again this will be accomplished through district-site number encoding.

Information required for districts and sites will vary from that which is required for buildings, structures, or objects. An example of this is the detailed geographic location description data which is requested for districts and sites only. Instructions provided with the form will define those items on the form required for each type of submittal.

- b. Property Map Form. Information describing the map or chart used to obtain the district or site location is submitted on this form. The information will be used to establish what accuracy or resolution can be expected from the geographic location data provided. This information is to be entered into the district or site record to aid in geographic retrieval operations.
- c. Property Photograph Form. Information such as photo credit, date of photography, and description of the view and direction of photography is submitted on this form for each photograph.

Information concerning the availability of these photographs will be included in the data bank. Individuals retrieving data concerning a district or site can then determine if photo coverage is available.

A manual and mechanical edit is planned for the information provided on the forms to ensure the accuracy and thoroughness of the data.

Examples of the proposed forms and instructions for their use are provided in Appendix A.

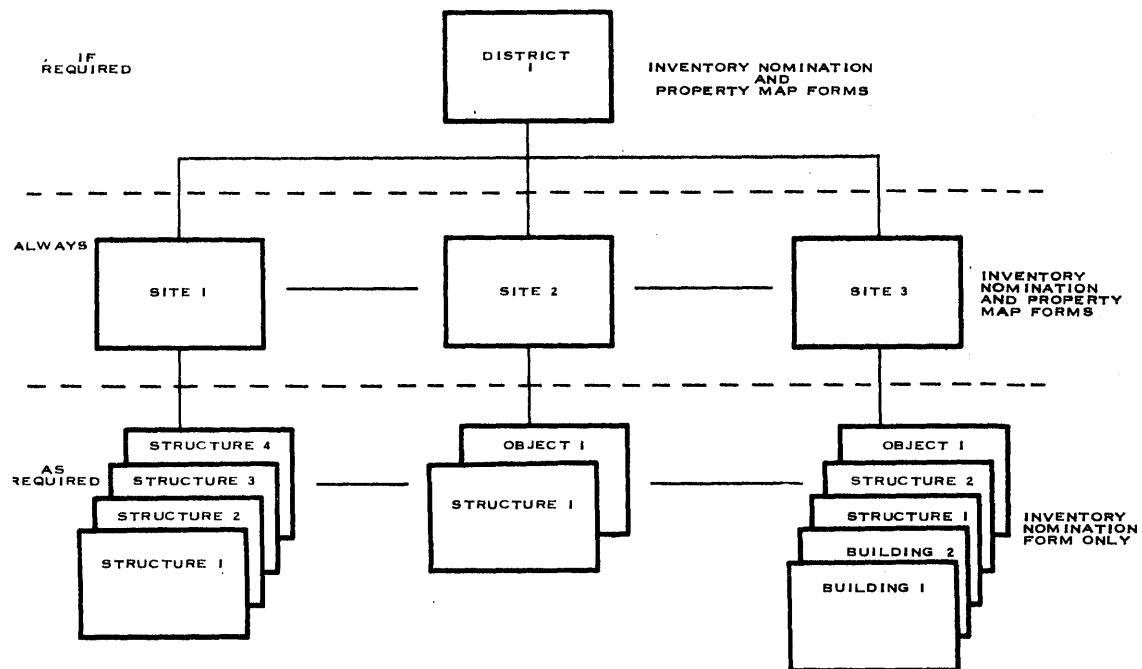
As an example, an Inventory-Nomination form would be prepared to describe an historic district such as the Georgetown Historic District in Washington, D.C. Each specific site within the district would then be entered on the Inventory-Nomination form. Finally, an Inventory-Nomination form for each structure, building, or object on these sites would be included in the submittal. A geographic description form would be provided for the district which is defined and for each site within the district. A flowchart describing the form usage and site identification encoding is shown in Figure 2-1.

If a property belongs to no historic district, the field for district will be filled with zeros; all properties (sites) without a district designation will appear as the first records within a state. Properties which are included in an historic district are found as the last records within a state-county grouping with the associated district descriptions.

Once the system at the National Register is established, reports to the submitting state liaison officer (listing those properties established in the National Register data base) can be made. If information was missing or in error on the submittal forms, correction requests can be indicated on these listings.

Update or change procedures will be left initially to the state liaison officer. A listing which would indicate those properties most likely to change status or those of a high priority nature should be provided to the states for periodic review. This can be done by setting up a rotating reinventory flag in the record by using data elements pertinent to property status and/or priority. Some of these data elements are as follows:

- a. Property ownership
- b. Acquisition status
- c. Significance rating
- d. Location
- e. Accessibility to the public.



ST	CTY	SITE NUMBER		STRUCTURE NO.	
		DIST.	SITE NO.		

- RECORD ENCODING

01	001	001	00000	000	
----	-----	-----	-------	-----	--

DISTRICT 1 DESCRIPTION RECORD

01	001	001	00001	000	
----	-----	-----	-------	-----	--

SITE 1 DESCRIPTION RECORD

01	001	001	00001	001	
----	-----	-----	-------	-----	--

STRUCTURE 1 DESCRIPTION RECORD

01	001	001	00001	002	
----	-----	-----	-------	-----	--

STRUCTURE 2 DESCRIPTION RECORD

01	001	001	00001	003	
----	-----	-----	-------	-----	--

STRUCTURE 3 DESCRIPTION RECORD

01	001	001	00001	004	
----	-----	-----	-------	-----	--

STRUCTURE 4 DESCRIPTION RECORD

01	001	001	00002	000	
----	-----	-----	-------	-----	--

SITE 2 DESCRIPTION RECORD

01	001	001	00002	001	
----	-----	-----	-------	-----	--

STRUCTURE 1 DESCRIPTION RECORD

01	001	001	00002	002	
----	-----	-----	-------	-----	--

STRUCTURE 2 DESCRIPTION RECORD

Figure 2-1. Submittal Forms Utilization and Record Encoding

A weighting algorithm can assign this flag during file update operations or when selecting records for formatting a monthly report for the state liaison officer. This algorithm can also select these properties on a time cycle determined by the calculated importance rating.

This report would supply the states with a list of those properties which require a review of status. If any change in the property status has occurred, change data or a new submittal could be initiated.

Procedures and forms for the initial submittal and change data must be provided as soon as possible to ensure the collection of proper inventory data. This suggested reinventory or rotating inventory procedure will help the states provide change data even when no procedures exist at the state level for determining which property to reinventory.

### Section 3

#### GEOGRAPHIC DESCRIPTION, SUBMITTAL AND ITS STORAGE

Since no time was provided to survey even a limited number of states concerning the availability of grid systems, maps, or survey data, previous experience with similar problems was used to formulate the opinions expressed here.

It is assumed that many states will have some form of map coverage available for the total area within their state. The departments within the state most likely to have this supporting material are the state highway department or various departments whose efforts fall in the geological or topographic areas of interest. The mapping, grid, and/or displacement systems used by these departments are usually more than adequate for the proposed geographic submittal requirement defined in this paper.

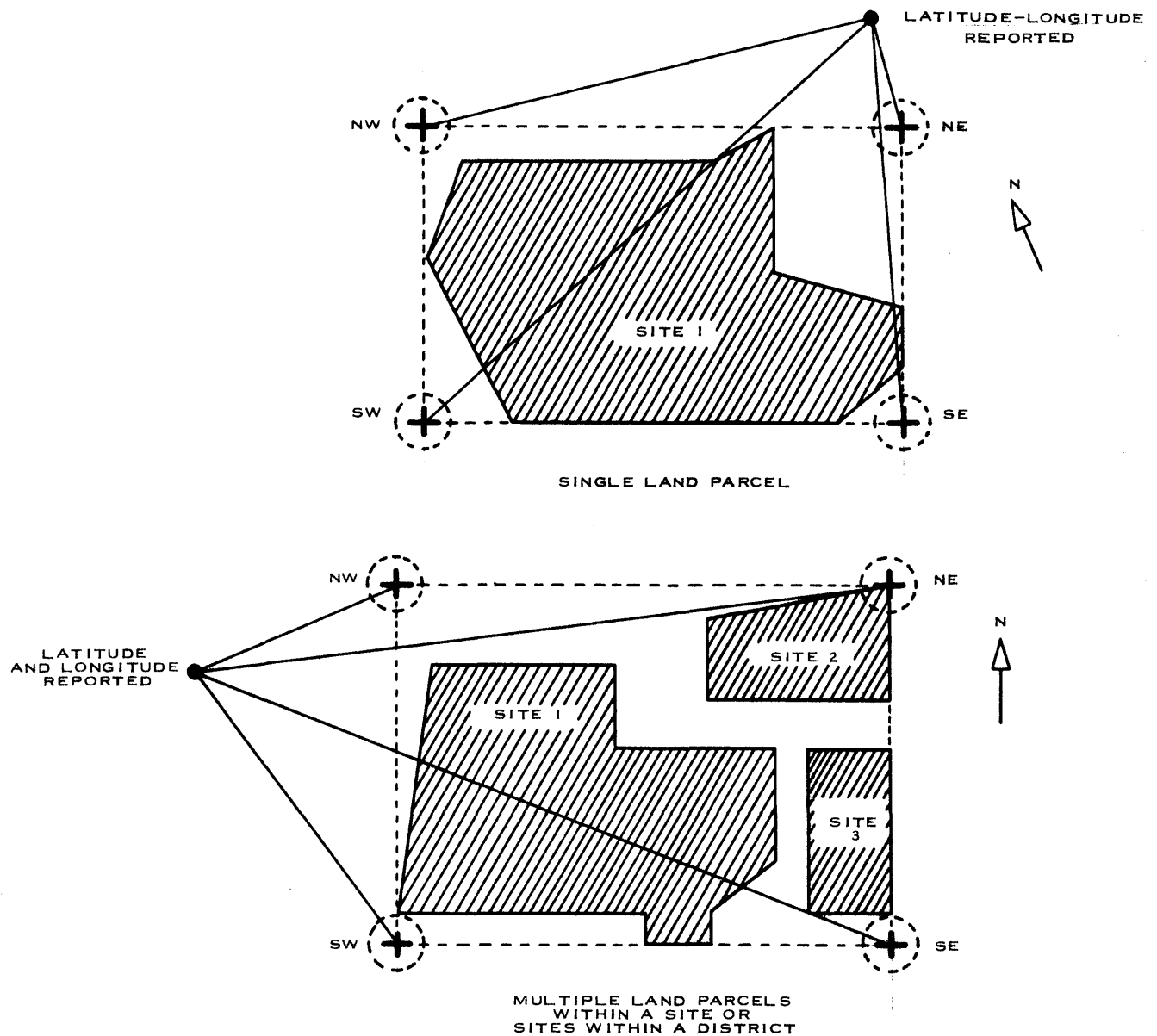
In requesting the individual states to supply the required geographic data, it may be suggested that they request support from such state departments. These groups may have all the necessary base maps and may even have other suggestions beyond those included in this document for obtaining the required geographic data.

After considering the many possible coordinate systems being used throughout the country, it is recommended that the National Register adopt the latitude-longitude representation of displacement for use in their system. In most cases, existing grid systems or displacement systems used by states are readily converted to latitude-longitude form. No one coordinate system is in use by every state, and, it is believed that a latitude-longitude displacement system would provide the utility necessary for current and future applications.

Most maps which could be used to determine site location have latitude-longitude grid systems annotated on them. If the located site is reported using latitude-longitude values in degrees, minutes, and seconds, a minimum resolution obtainable between points on the ground would be 101 feet. This is the approximate distance of 1 second of latitude or longitude. Further resolution can be obtained by using tenths of a second if possible. In any case, the accuracy of the site placement will depend upon three things: the scale and quality of the map used, accuracy of the site placement on the reference map, and the interpolation technique used to put latitude-longitude values on reported points. The United States Geological Survey 7 1/2 minute quadrangles provide an excellent scale-of-map to enter intermediate or large area sites. The scale on these maps is about 1 inch to 2000 feet. A second of distance would then be approximately 1/20 of an inch. Sites of 1 acre or larger are placeable at this scale and for city size lots of an acre or less, maps with a scale of from 1 inch to 40 feet up to 1 inch to 500 feet are much more desirable. If maps of this scale are used, tenths of a second are reportable, thus improving the actual positioning of the site in the data base.

The scale of the map used is requested in the geographic data submittal form for each site. This will aid in determining the resolution obtainable from reported site location coordinate values. This is necessary to adjust subsequent search or retrieval parameters to ensure selection of those sites included in an area of interest.

The actual representation of latitude and longitude in the stored data base should be in degrees and one hundred thousandths of a degree (five decimal representation of minutes and seconds). This provides a value which is readily usable in geo-retrieval and conversion algorithms. In order to simplify the reporting of the geographic location of a district or site, it is recommended that a rectangle be superimposed on a grid which encompasses the entire area being reported, (see Figure 3-1). The four latitude and longitude values for the vertices of the rectangles are the only reported points. If the site is excessively small, or if the method of scaling used to obtain the latitude-longitude values negates the possibility of defining the area with a rectangle, only the value of the centroid of the site should be reported.



*Figure 3-1. A Rectangle Used to Define the Location of Districts or Sites*

If this approach is used to locate districts or sites, the nominator need only compute the four sets of figures for the rectangle. A great deal of effort is thus avoided because a great number of sites will have more than four vertices in the polygon used to describe the site as well those which are non-contiguous areas. Occasions will arise when some states will not be able to obtain the geographic location of a site by direct conversion of known values in a local coordinate system to latitude and longitude for submittal. Alternative techniques must be provided. The following is a group of techniques to be used and structured according to preference of use:

- a. Direct conversion from a state coordinate system (state plane coordinates, rectangular coordinates or indexed grid system) to the latitude and longitude values for each corner of the rectangle encompassing the district or site which has been located on state provided maps. This should be done to the maximum resolution obtainable in the existing coordinate or grid systems.
- b. The establishment of the defining rectangle on existing plat or location survey maps which can then be oriented to known geodetic control points by simple triangulation.

If the site or district has never been located ( in a geographic sense) by a department in the state (using an adopted coordinate or grid system) or if there are no usable or available plat maps, the following techniques could be used to derive the necessary information:

- c. Make a sketch of the site obtaining distances from existing property descriptions and orient it with a north arrow. Sketch roads and obtain distances d1, d2, and d3 in the most accurate method available (see F Figure 3-2). Using the appropriate scale adjustment, superimpose the site on a USGS quadrangle sheet or one of the following (whichever is available or provides the best results, maximum resolution or utility):
  1. National Park Service or Forest Service maps
  2. State produced road maps
  3. Oil company or other geological survey maps
  4. Atlas maps or gas company road maps.

All these maps have annotated standard grids with latitude and longitude values provided. An interpolation of the latitude and longitude values for each vertex in the rectangle encompassing the site will probably be accurate enough for the purposes of this system.

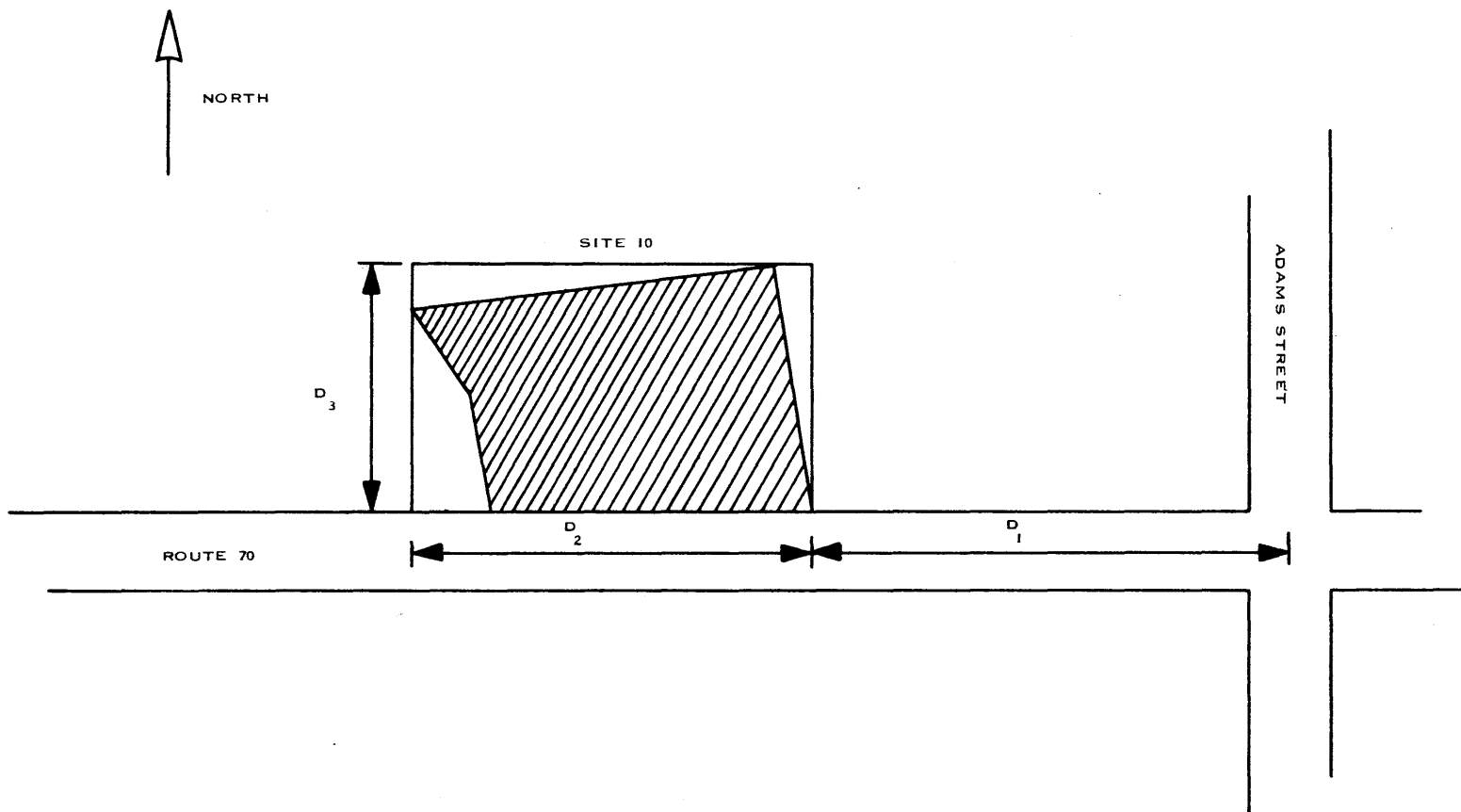


Figure 3-2. Example of Grid Placement

A more complex situation is shown in Figure 3-3. Even with a site as irregular as this or one not readily associated with bordering roads, the site is easily placed by using triangulation done with only right triangles. This site is then easily transferred to the available map by scaling the distances obtained from the formation of the rectangle surrounding the site.

An alternative to the determination and submittal of latitude-longitude values by the state liaison officer is the use of a coordinate reader or digitizer by the National Register group. Each site graphic (drawing or map) to be submitted would have coordinate values created for the identifying vertices or centroid by the use of this device. The submitted map or graphic would be mounted on the drafting table of the device. A cursor would be positioned at each point to be entered and an x-y value for the point would be mechanically produced. These values (created by a coordinate reader) are in the form peculiar to the specific device being employed. They are usually in the range of 5 digits and sign for the x and y axes and are linear counts of the movement of the cursor from a selected origin point on the surface of the table. The number of counts per inch of movement is usually selectable and varies on the average available equipment from 50 to 1000 counts per inch.

A coordinate value of this form must be converted to the representation required in the data base, in this case, latitude-longitude. Two factors must be considered in this process: the origin point value and alignment of the graphic, and the projection and scale of the map or graphic being used. Knowing these factors, the digitizer values are readily converted to the required form of latitude-longitude (degrees, and one hundred thousandths of a degree).

As previously mentioned, the graphic which represents the site must have a point or points identified geodetically in latitude and longitude (origin points). The values which identify the origin point are entered and all subsequent points entered are displacements from this point or points.

The digitizer approach (see Figure 3-4) obtains an accuracy and ease of determination of coordinate data which far exceeds that obtainable in a manual interpolation process. It is also possible to enter more points. This device's use

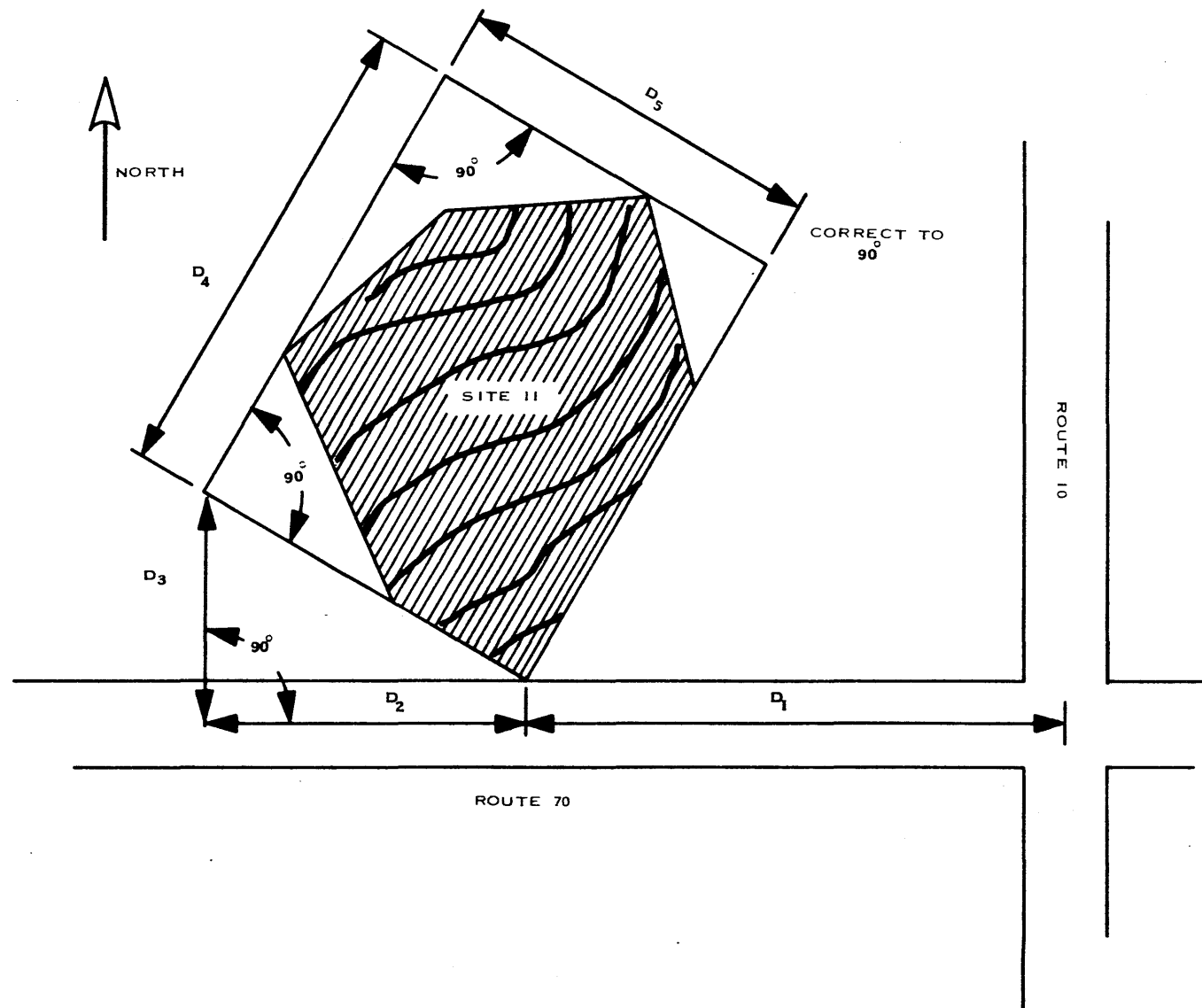


Figure 3-3. An Example of Grid Placement

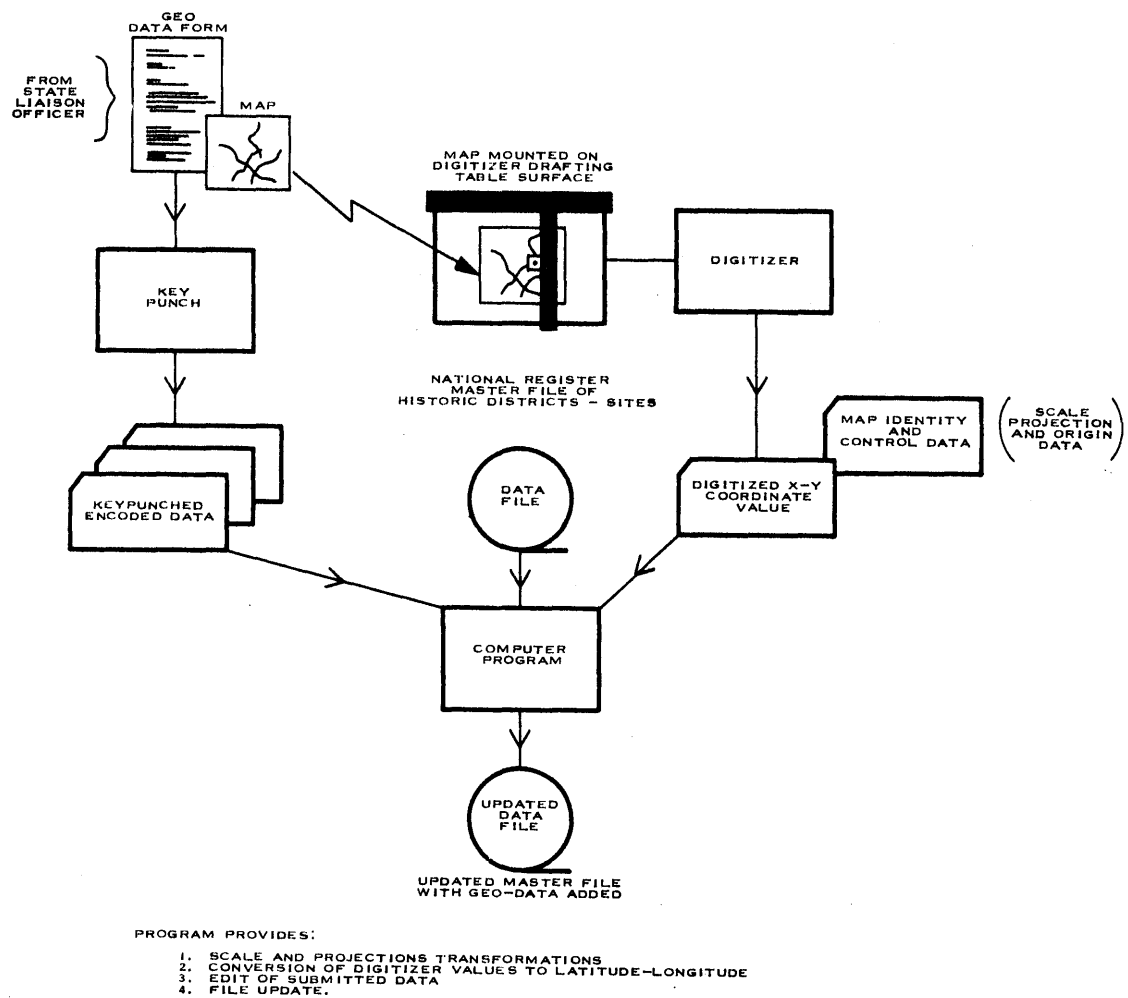


Figure 3-4. Mechanical Digitizing of Geo-Coordinate Data

by the National Register group could also provide a standardized method and accuracy of site location determination not necessarily obtainable from 50 or more sources at the state level.

The accuracy of devices of this type varies according to cost. A standard deviation of  $\pm 5$  mils is obtainable in the encoding circuitry of such equipment with table surface flatness to  $\pm 15$  mils. Depending on the material used in making the map, accuracy of the source data, scale of the map, and the device characteristics, varying degrees of accuracy can be obtained from use of this type equipment. In any case it will certainly produce better results than those which are obtainable by simple manual approaches.

## Section 4

### POSSIBLE SOFTWARE APPROACH

In establishing the data elements to be included in the previously defined system it was obvious that some form of a general file processing system such as the IBM GIS System (Generalized Information System) or S/360 FFS (Formatted File System) might be appropriate. These systems provide a file maintenance, record retrieval, and output formatting capability. (See Appendix B for a description of these systems.)

Programming for systems of this type is usually done in a macro form of a language and data elements defined in system through field and file dictionaries. File maintenance, retrieval or query parameters, and requested format requirements are all defined in the system through this programming language.

Information systems of this type provide a language which is readily usable with little training. Through this language a standard programming approach is also possible within the using organization. Since a single application such as the National Register site file would not justify use of such a system, other applications would be required which would also use it.

If this is not possible COBOL or PL/I could be used as the programming system. These languages provide a lower level capability and do not directly provide functions included in general information processing systems (file maintenance retrieval and update). These types of routines are created by the application programmer. He does this by defining the data handling requirements in the language provided by the programming system in a procedural manner. These languages require formal programmer training and require more time for the programming of new user requests. See Appendix C for a description of these systems.

The files created for use by such a system can maintain a master-detail record relationship or hierarchy. Retrieval of detail information can be accomplished by recognizing or satisfying query requirements with data found in the master record for a grouping.

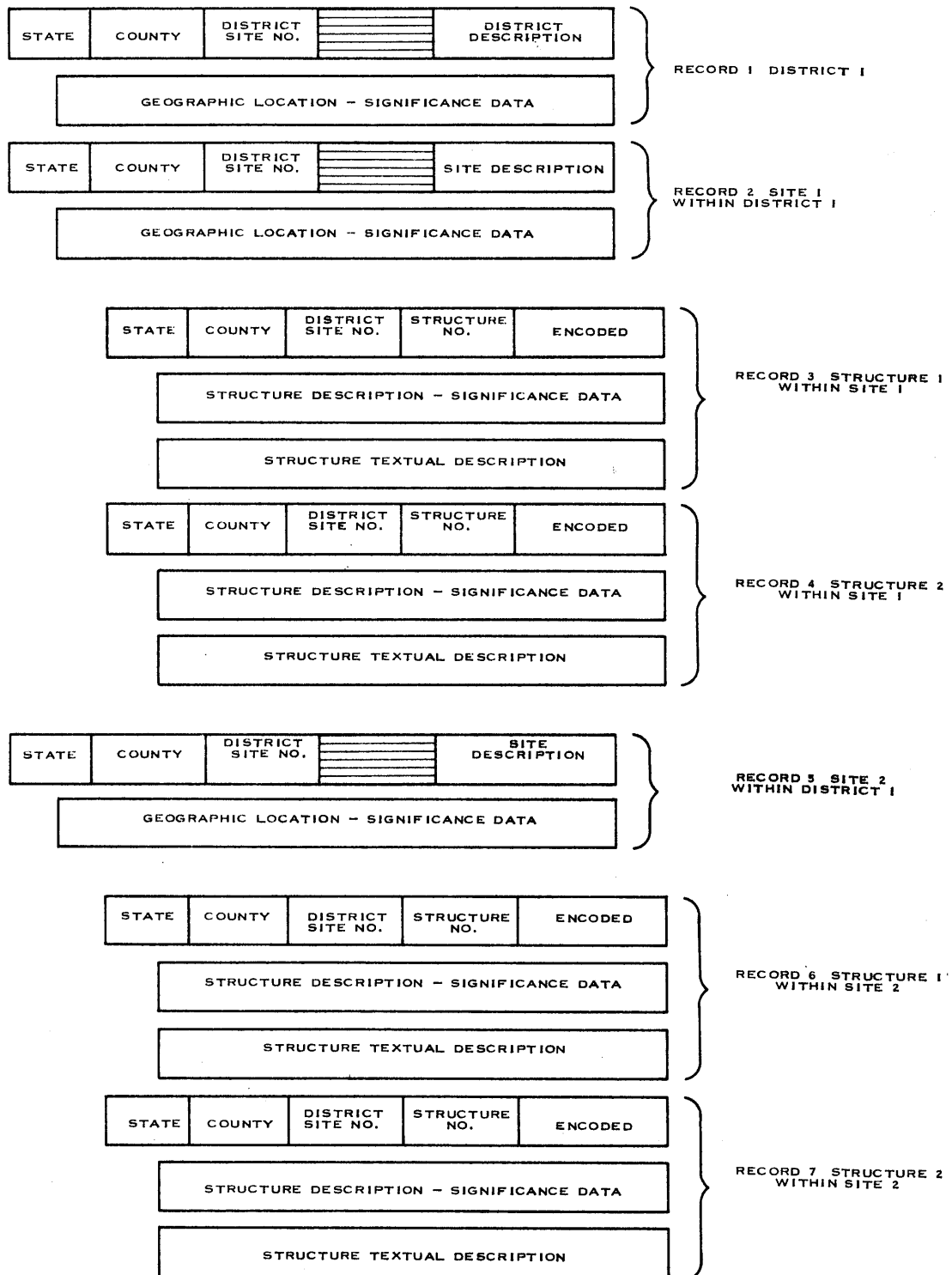
By assembling the information collected on the proposed forms, a file containing district-site encoded descriptions, geographic location, structure-object inventory, and textual district-site-structure descriptions can be created. An example of a suggested record relationship and data organization is shown in Figure 4-1.

Since the system in its initial phases does not require online access (teleprocessing capability), a sequential file access method using magnetic tape storage for the basic file seems most practical. This form of file is easily converted to a direct access form of storage such as disk storage to support a possible future requirement for remote terminal access.

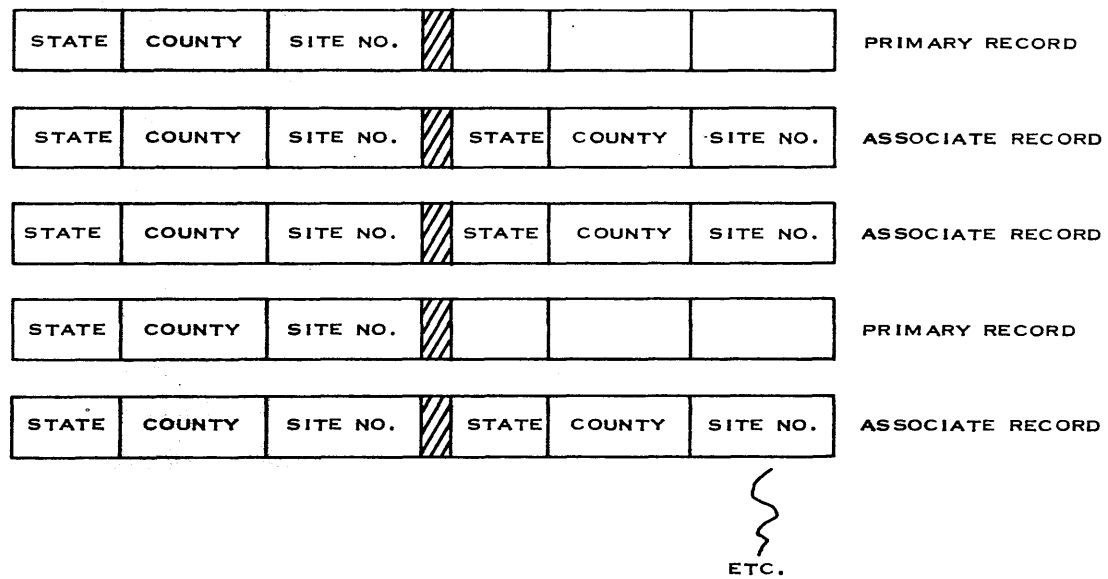
To facilitate retrieval of site data where the site itself may be located in more than one county or state, a cross index of this information is necessary.

This file would contain associated state and county data so that if the primary state and/or county encoded data for the site is not being used as the retrieval parameter, the primary record can be located without doing multiple runs against the basic file. An example of this file structure for the Site Cross Index is shown in Figure 4-2.

Two methods of accessing the data stored in these files are possible. The first is the conventional approach of selecting the records desired by their unique identifiers (state-county-site number) and/or conditioning their selection on data within the record itself (public land, private land parks, etc.). The second is identifying or selecting of sites, etc., by defining a geographic area of interest. The first method of selecting data is readily accomplished in the Formatted File System; the second deserves some discussion here.



*Figure 4-1. Register File Organization*



*Figure 4-2. Associate State County Index*

Sites or properties defined by establishing latitude-longitude values for points at the vertices of bounding polygons are positioned in a linear geographic displacement system and are stored in the data base. If an area being considered for an urban renewal project is also defined as a polygon, it can be used as a search requirement against this data. This polygon defined in latitude-longitude is compared to the sites in the data bank and those polygons representing sites which overlay or intersect with it, selected using geo-search techniques.

Geo-retrieval packages work with geometric forms such as points, polygons, circles, and vectors. The geo-retrieval package, produced by the Graphic Systems Department of the IBM Federal Systems Division, which can be used with these generalized information systems provides the following functions:

- a. Point coincidence
- b. Point within a circle
- c. Point-vector intersection
- d. Point within a polygon
- e. Vector-vector intersection
- f. Vector-circle intersection
- g. Vector-polygon intersection
- h. Circle-polygon intersection
- i. Circle-circle intersection
- j. Polygon-polygon intersection.

A paper describing these routines is provided in the Appendix D of this document.

Using the geographic description of the site which becomes a geo-index to the system, search requirements in the form of polygons, circles, points, or vectors can be used to select site data from the file. Coordinate data establishing freeway right-of-way, urban renewal project areas, or land to be acquired for utility routes is entered and those sites affected are determined by use of these geo-retrieval functions. The format and sequence of presentation is a matter of choice by the user of such a system. Again, through the provided language, the user defines the sequence and format for the report he is to produce. In the

case where text is being selected, margins and hyphenation are possible and the output can be directly fed to linotype or photocomposer equipment for producing the necessary electros for a publishing process. The flowchart depicting the suggested system is provided in figures 4-3 and 4-4.

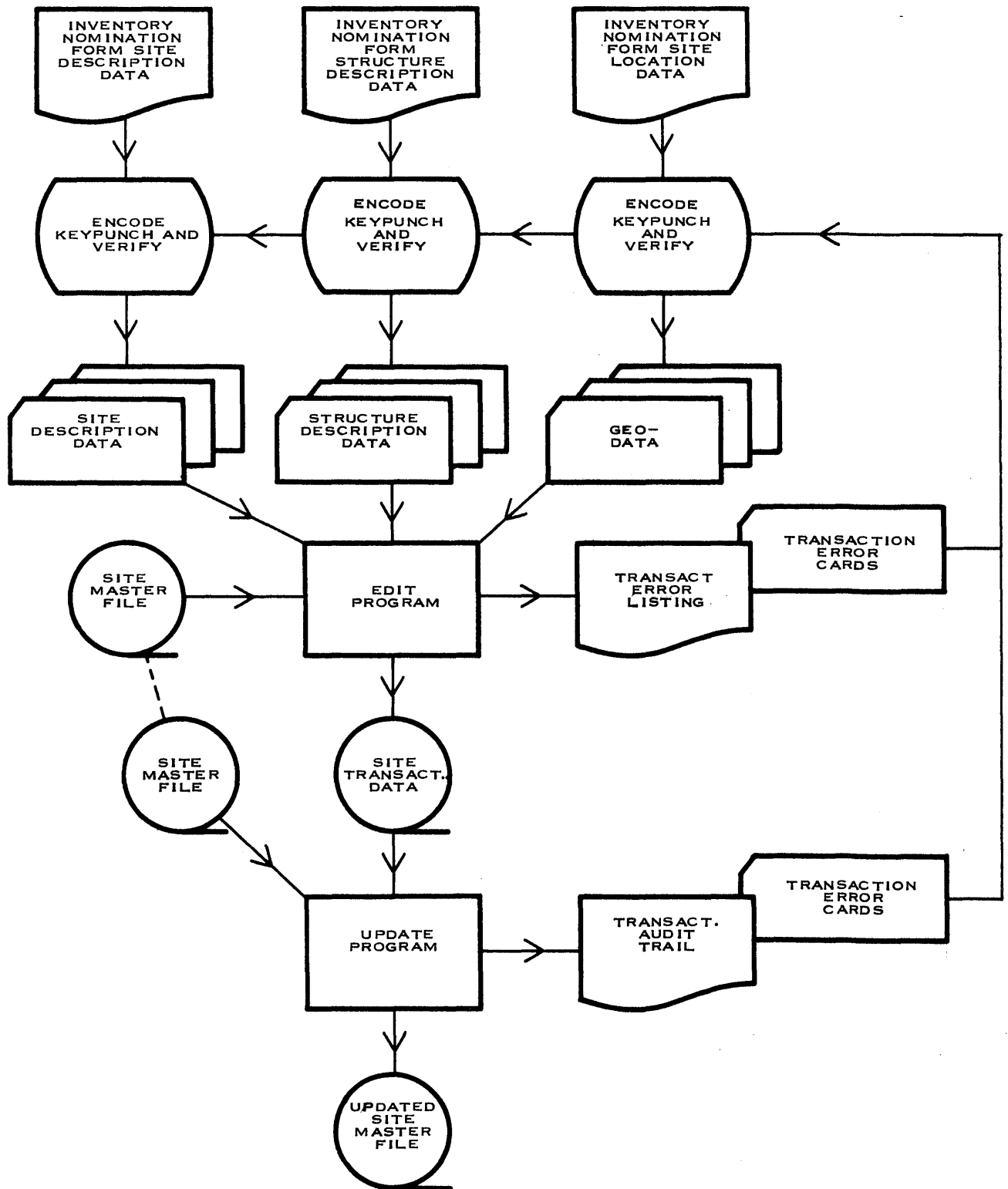


Figure 4-3. System Data Flow—File Maintenance and Edit

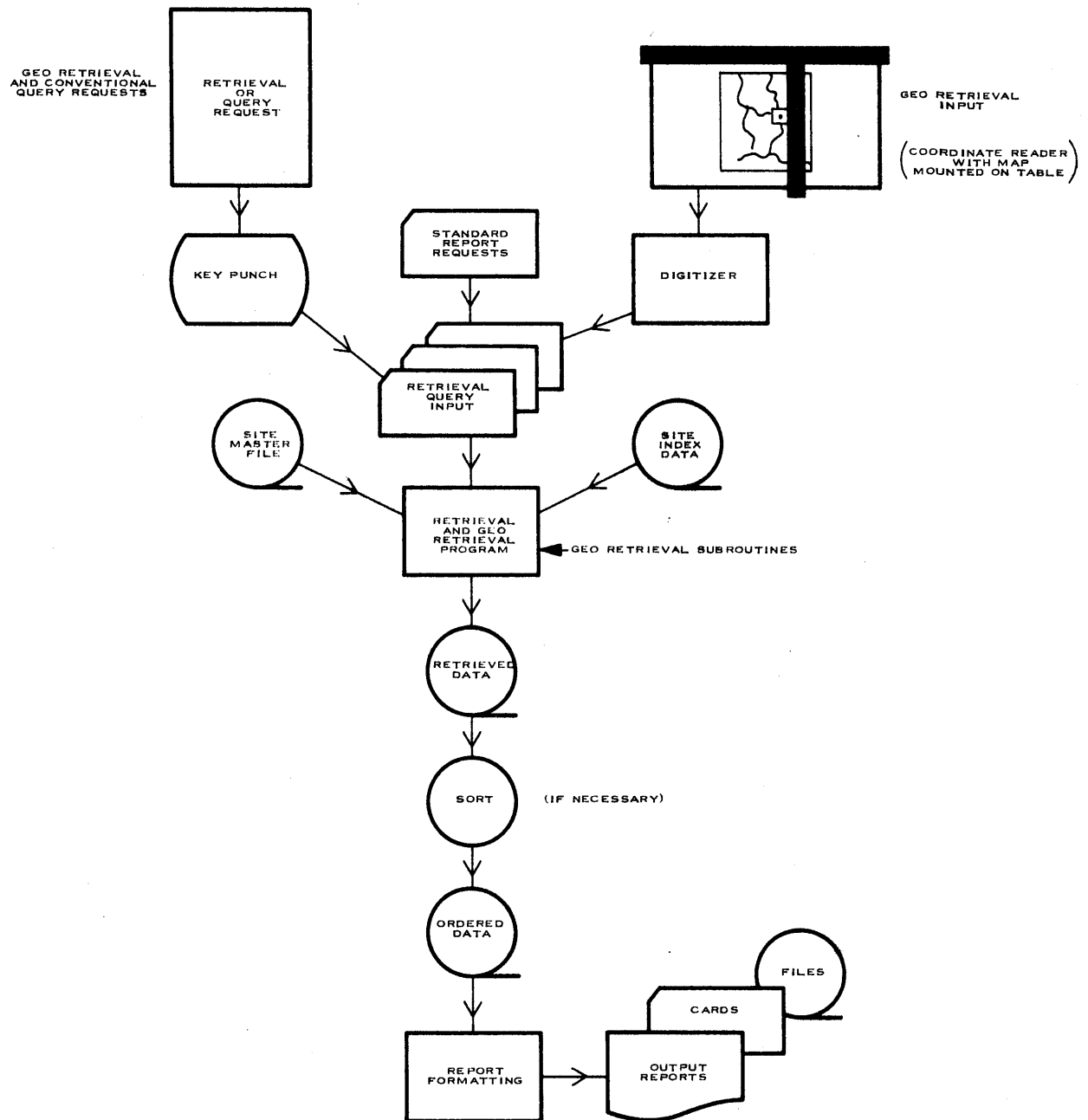


Figure 4-4. System Data Flow Retrieval and Output

## Section 5

### SUMMARY

The system and software approach presented in this paper does not produce any major design or implementation obstacles insofar as the automated process is concerned. The actual collection of the information at the state level is the function which deserves the most attention.

The geographic data requested in the nominating forms seems to be the data items which will prove the most difficult to supply. In defining what form this data should take, consideration was given to this fact. The data requested was the minimum necessary to provide a usable approximation of the property location.

As previously stated, the accuracy of the property location depends upon three things: the scale and quality of the maps used; the care taken in superimposing the property on the reference map; and the procedure used to interpolate the latitude-longitude values required.

Since the location data submitted will be used in subsequent retrieval operations, all that can be done to obtain and improve upon the accuracy of this data should be considered. The appropriate state agencies which have topographic and/or cartographic responsibilities within their character should be consulted to determine if supporting materials (maps, charts, grid systems), techniques, or other resources can be provided to help determine precise property location. It certainly would be desirable to create the latitude-longitude values which locate the site on a coordinate reaching device at the National Register. The output would then be processed by computer programs which would provide the necessary transformation of the digitized coordinate values into latitude and

longitude. This would relieve the provider of the site graphic of the task of interpolating the latitude and longitude values. This would improve the accuracy of the site placement in the data bank.

The programming required to implement such an approach is not formidable. If a general information processing system is used, file maintenance, query, and report formatting can be accomplished without extensive programming. Languages provided with such systems allow the non-programmer to define query parameters and report formats. These systems also provide for the use of user subroutines if the program functions required in the application are not included in the basic package. In most cases, the geographic retrieval routines would be user-supplied. Programs which convert latitude-longitude values into the appropriate form for storage, convert absolute digitizer coordinate values into latitude-longitude, or perform other scale or projection transformations must also be provided as user subroutines.

The reports for management purposes or other operational needs are easily produced in such a programming system. Special reports and one-time queries are programmed by the user in the language provided with the system which requires neither programming experience nor major assistance from a trained programmer.

The National Register with such support could assure timely and accurate information for those needing it. If future requirements dictate online terminal access, these programming systems provide this capability within their structure and the transition to this mode of operation is simple.

Since the National Register is just beginning the collection of data from the States, the automated system should be defined as soon as possible in order to take advantage of this opportunity. Necessary forms, data elements to be included in the files, and reports to be produced should be defined and a cost analysis should be accomplished. If the cost analysis indicates this is a worthwhile project, implementation should be accomplished as soon as possible.

**Appendix A**

**Proposed National Register Data Collection Forms  
and Instructions**

NATIONAL REGISTER OF HISTORIC PLACES  
INVENTORY - NOMINATION FORM

(Type all entries - complete applicable sections)

STATE:	
COUNTY:	
FOR NPS USE ONLY	
ENTRY NUMBER	DATE

SEE INSTRUCTIONS

<b>1. NAME</b>									
COMMON:									
AND/OR HISTORIC:									
<b>2. LOCATION</b>									
STREET AND NUMBER:									
CITY OR TOWN:									
STATE				CODE		COUNTY:		CODE	
<b>3. CLASSIFICATION</b>									
CATEGORY (Check One)			OWNERSHIP			STATUS		ACCESSIBLE TO THE PUBLIC	
District <input type="checkbox"/>	Building <input type="checkbox"/>		Public <input type="checkbox"/>		Public Acquisition: <input type="checkbox"/>	Occupied <input type="checkbox"/>	Yes:		
Site <input type="checkbox"/>	Structure <input type="checkbox"/>		Private <input type="checkbox"/>		In Process <input type="checkbox"/>	Unoccupied <input type="checkbox"/>	Restricted	<input type="checkbox"/>	
Object <input type="checkbox"/>			Both <input type="checkbox"/>		Being Considered <input type="checkbox"/>	Preservation work in progress <input type="checkbox"/>	Unrestricted	<input type="checkbox"/>	
No: <input type="checkbox"/>									
PRESENT USE (Check One or More as Appropriate)									
Agricultural <input type="checkbox"/>	Government <input type="checkbox"/>	Park <input type="checkbox"/>	Transportation <input type="checkbox"/>	Comments	<input type="checkbox"/>				
Commercial <input type="checkbox"/>	Industrial <input type="checkbox"/>	Private Residence <input type="checkbox"/>	Other (Specify) <input type="checkbox"/>						
Educational <input type="checkbox"/>	Military <input type="checkbox"/>	Religious <input type="checkbox"/>							
Entertainment <input type="checkbox"/>	Museum <input type="checkbox"/>	Scientific <input type="checkbox"/>							
<b>4. OWNER OF PROPERTY</b>									
OWNERS NAME:									
STREET AND NUMBER:									
CITY OR TOWN:				STATE:		CODE		STATE:	
<b>5. LOCATION OF LEGAL DESCRIPTION</b>									
COURTHOUSE, REGISTRY OF DEEDS, ETC:									
STREET AND NUMBER:									
CITY OR TOWN:				STATE		CODE		COUNTY:	
APPROXIMATE ACREAGE OF NOMINATED PROPERTY:									
<b>6. REPRESENTATION IN EXISTING SURVEYS</b>									
TITLE OF SURVEY:									
DATE OF SURVEY:				Federal <input type="checkbox"/>		State <input type="checkbox"/>		County <input type="checkbox"/>	
DEPOSITORY FOR SURVEY RECORDS:				Local <input type="checkbox"/>					
STREET AND NUMBER:									
CITY OR TOWN:				STATE:		CODE		ENTRY NUMBER	
								DATE	

# 7. DESCRIPTION

CONDITION	(Check One)					
	Excellent <input type="checkbox"/>	Good <input type="checkbox"/>	Fair <input type="checkbox"/>	Deteriorated <input type="checkbox"/>	Ruins <input type="checkbox"/>	Unexposed <input type="checkbox"/>
INTEGRITY	(Check One)			(Check One)		
	Altered <input type="checkbox"/>	Unaltered <input type="checkbox"/>	Moved <input type="checkbox"/>	Original Site <input type="checkbox"/>		

DESCRIBE THE PRESENT AND ORIGINAL (If known) PHYSICAL APPEARANCE

SEE INSTRUCTIONS

**B. SIGNIFICANCE****PERIOD** *(Check One or More as Appropriate)*Pre-Columbian ☐16th Century ☐18th Century ☐20th Century ☐15th Century ☐17th Century ☐19th Century ☐**SPECIFIC DATE(S)** *(If Applicable and Known)***AREAS OF SIGNIFICANCE** *(Check One or More as Appropriate)*Aboriginal ☐Education ☐Political ☐Urban Planning ☐Prehistoric ☐Engineering ☐

Religion/Phi-

Other *(Specify)* ☐Historic ☐Industry ☐losophy ☐Agriculture ☐Invention ☐Science ☐Art ☐Landscape ☐Sculpture ☐Commerce ☐Architecture ☐

Social/Human-

Communications ☐Literature ☐itarian ☐Conservation ☐Military ☐Theater ☐Music ☐Transportation ☐**STATEMENT OF SIGNIFICANCE** *(Include Personages, Dates, Events, Etc.)*

## 9. MAJOR BIBLIOGRAPHICAL REFERENCES

## 10. GEOGRAPHICAL DATA

LATITUDE AND LONGITUDE COORDINATES DEFINING A RECTANGLE LOCATING THE PROPERTY			O R	LATITUDE AND LONGITUDE COORDINATES DEFINING THE CENTER POINT OF A PROPERTY OF LESS THAN ONE ACRE		
CORNER	LATITUDE	LONGITUDE		LATITUDE	LONGITUDE	
	Degrees Minutes Seconds	Degrees Minutes Seconds		Degrees Minutes Seconds	Degrees Minutes Seconds	
NW	° ' "	° ' "		° ' "	° ' "	
NE	° ' "	° ' "		° ' "	° ' "	
SE	° ' "	° ' "		° ' "	° ' "	
SW	° ' "	° ' "		° ' "	° ' "	

LIST ALL STATES AND COUNTIES FOR PROPERTIES OVERLAPPING STATE OR COUNTY BOUNDARIES

STATE:	CODE	COUNTY	CODE
STATE:	CODE	COUNTY:	CODE
STATE:	CODE	COUNTY:	CODE
STATE:	CODE	COUNTY:	CODE

## 11. FORM PREPARED BY

NAME AND TITLE:		
ORGANIZATION	DATE	
STREET AND NUMBER:		
CITY OR TOWN:	STATE	CODE

## 12. STATE LIAISON OFFICER CERTIFICATION

As the designated State Liaison Officer for the National Historic Preservation Act of 1966 (Public Law 89-665), I hereby nominate this property for inclusion in the National Register and certify that it has been evaluated according to the criteria and procedures set forth by the National Park Service. The recommended level of significance of this nomination is:

National ☐ State ☐ Local ☐

Name \_\_\_\_\_

Title \_\_\_\_\_

Date \_\_\_\_\_

## NATIONAL REGISTER VERIFICATION

I hereby certify that this property is included in the National Register.

\_\_\_\_\_  
Chief, Office of Archeology and Historic Preservation

Date \_\_\_\_\_

ATTEST:

\_\_\_\_\_  
Keeper of The National Register

A-4  
Date \_\_\_\_\_

SEE INSTRUCTIONS

**NATIONAL REGISTER OF HISTORIC PLACES  
INVENTORY - NOMINATION FORM**

*(Continuation Sheet)*

STATE	
COUNTY	
FOR NPS USE ONLY	
ENTRY NUMBER	DATE

*(Number all entries)*

**NATIONAL REGISTER OF HISTORIC PLACES  
PROPERTY MAP FORM**

*(Type all entries - attach to or enclose with map)*

STATE	
COUNTY	
FOR NPS USE ONLY	
ENTRY NUMBER	DATE

SEE INSTRUCTIONS

<b>1. NAME</b>			
COMMON:			
AND/OR HISTORIC:			
<b>2. LOCATION</b>			
STREET AND NUMBER:			
CITY OR TOWN:			
STATE:	CODE	COUNTY:	CODE
<b>3. MAP REFERENCE</b>			
SOURCE:			
SCALE:			
DATE:			
<b>4. REQUIREMENTS</b>			
TO BE INCLUDED ON ALL MAPS			
1. Property boundaries where required.			
2. North arrow.			
3. Latitude and longitude reference.			

**NATIONAL REGISTER OF HISTORIC PLACES  
PROPERTY PHOTOGRAPH FORM**

*(Type all entries - attach to or enclose with photograph)*

STATE	
COUNTY	
FOR NPS USE ONLY	
ENTRY NUMBER	DATE

SEE INSTRUCTIONS

<b>1. NAME</b>			
COMMON:			
AND/OR HISTORIC:			
<b>2. LOCATION</b>			
STREET AND NUMBER:			
CITY OR TOWN:			
STATE:	CODE	COUNTY:	CODE
<b>3. PHOTO REFERENCE</b>			
PHOTO CREDIT:			
DATE OF PHOTO:			
NEGATIVE FILED AT:			
<b>4. IDENTIFICATION</b>			
DESCRIBE VIEW, DIRECTION, ETC.			

## INSTRUCTIONS

### USING THE NATIONAL REGISTER FORMS

General: These forms are intended for the use of the States in nominating properties for entry in the National Register to effect protection provided by P.L. 89-665. The National Park Service accepts nominations only through the State Liaison Officer.

A. INVENTORY-NOMINATION FORM: (Form 10-300)

Purpose: This form contains the basic written data required to nominate a property for entry in the National Register. Except where otherwise noted, all code numbers will be entered by the State Liaison Officer based on information supplied by the National Park Service.

Completing the Form:

1. NAME: Current common name of the property and any historical name(s).
2. LOCATION: Written geographic description of property location. Identify the township if applicable.
3. CLASSIFICATION:  
Category (check one)

District: A geographically definable area, urban or rural, possessing a significant concentration or linkage of sites, buildings, structures, or objects unified by past events or aesthetically by plan or physical development.

Site: The location of an event, building, structure, or object.

Building: A structure created to shelter any form of human activity.

Structure: A work constructed by man.

Object: A material thing of functional, aesthetic, cultural, historical, or scientific value that is usually, by nature or design, movable.

Ownership (check no more than two)

Status (check one)

Accessible to Public (check one) Indicates whether the general public has direct access to the property. Restricted access would include access by appointment, scheduled hours, etc.

Present Use (check one or more)

4. OWNER OF PROPERTY: Name and address of owner at the date of nomination. Omit entry where there is a large multiple public and private ownership (i.e. districts).
5. LOCATION OF LEGAL DESCRIPTION: Reference to location of current property title at the date of nomination.

The following are not required:

1. chain of title
2. copy of title
3. book and page reference to title.

List the approximate acreage for the nominated property.

6. REPRESENTATION IN EXISTING SURVEYS: Many properties to be nominated have been recognized in existing inventories or surveys. This blank serves as a reference to identify such surveys and locates the repository for the records the surveys produced. Copies of existing survey records are not required. Use continuation sheet (Form 10-300a) if necessary.
7. DESCRIPTION:

Condition (check one)

Integrity (check one)

Description: A concise, factual written description of the property, including any known information of original condition and later alterations or changes. Use continuation sheet (Form 10-300a) if necessary.

8. SIGNIFICANCE:

Period (check one or more)

Specific Date: If the property has a specific date of primary significance, please indicate.

Areas of Significance: Check one or more as appropriate to indicate the major significance of the property.

Statement of Significance: A concise, factual statement of the reason(s) for the property's entry in the National Register. Use continuation sheet (Form 10-300a) if necessary.

9. BIBLIOGRAPHICAL REFERENCE: List the sources of the historical, architectural, or archeological information given in this form, especially the major published works related to the property.

10. GEOGRAPHICAL DATA:

General: See the detailed instructions for the submission of maps, Form 10-301, Property Map Form.

Requirements:

1. The location of each property must be graphically shown on a map.
2. Boundaries must be shown on a suitable map for:
  - a. All districts nominated for the National Register.
  - b. All sites nominated for the National Register.
  - c. Any building, structure or object where the size of the property to be nominated for the National Register exceeds an acre or where the proposed boundary does not coincide with the existing recorded legal description of the property. In such cases, the map should clearly show the variances.

Latitude and Longitude Coordinates (Use only one of the following)

1. When the property involves an acre or more of land, circumscribe its boundaries by a rectangle and determine the coordinates for the four corners of the rectangle.
2. For a property covering less than one acre determine the coordinates of its center point.

If a property overlaps state or county boundaries, list all states and/or counties within which the property lies.

11. FORM PREPARED BY: This identifies the compiler of the form.
  12. STATE LIAISON CERTIFICATION: To be completed only by the State Liaison Officer. It certifies that the property has been evaluated and reviewed at the state level according to requirements outlined in Chapters 2 and 3 listed in the National Park Service document Grants for Historic Preservation: Guide to State Participation, prior to being forwarded to the National Park Service. The recommended level of significance represents the opinion of the state and is for informational purposes only; distinctions will not appear in the printed edition of the National Register.
- National Register Verification: To be completed only by the National Park Service when the property is entered in the National Register.

B. PROPERTY MAP FORM (Form 10-301)

Requirement: One property map form should be attached to each map submitted.

Purpose: The basic data for National Register entries will eventually be maintained by an automatic data processing system. The following instructions are provided to permit the determination of the special required geographic data.

It is assumed that states have available some form of map coverage for the total area within their boundaries. The departments within the state most likely to have this material are the state highway department or those departments whose efforts fall in the geological or topographical areas of interest. The mapping systems used by these departments are usually more than adequate for the geographic requirements of the National Register. It is suggested that the State Liaison Officer consult with and request support from such state departments. These groups may have all the necessary base maps and may even have other suggestions, beyond those included in this document, for obtaining the necessary geographic data.

The National Register has adopted the latitude-longitude system in locating historic property. No one coordinate system is used by every state. It is believed that latitude-longitude provides maximum usability for current and future needs.

The accuracy of the property location on a map depends upon three things:

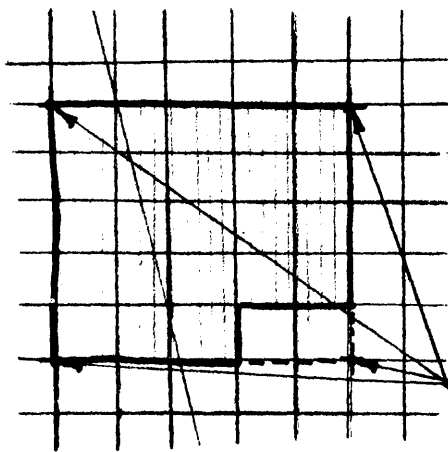
1. the scale and quality of the map used
2. the accuracy of the individual marking the property on the map
3. the accuracy used in determining latitude-longitude readings.

The maps of the United States Geological Survey, with 7 1/2 minute quadrangles, provide an excellent scale upon which to record intermediate or large areas. The scale on these maps is about one inch to 2,000 feet. One second of distance, therefore, equals approximately 1/20th of an inch. Sites one acre or larger can be placed at this scale. For city size lots of an acre or less, maps with a scale of one inch to 40 feet or one inch to 500 feet are much more desirable.

Completing the Form:

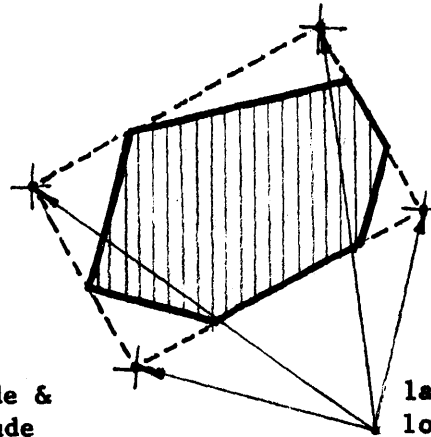
1. NAME: Current common name of the property and any historical names.
2. LOCATION: Written geographic description of property location. Identify the township if applicable.
3. MAP REFERENCE: Identify the source, scale, and date of the map used in locating the property and included as a part of this nomination.
4. REQUIREMENTS: To determine the latitude-longitude coordinates of a property, one of the following two steps should be followed according to the size of the property to be recorded:

# EXAMPLES FOR LATITUDE AND LONGITUDE DETERMINATIONS



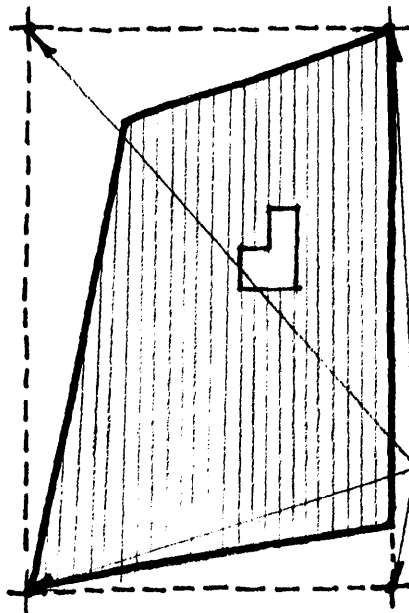
latitude &  
longitude  
coordinates

DISTRICT



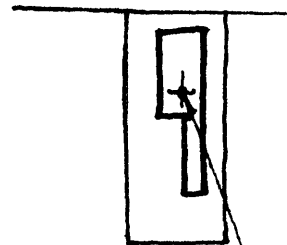
latitude &  
longitude  
coordinates

SITE



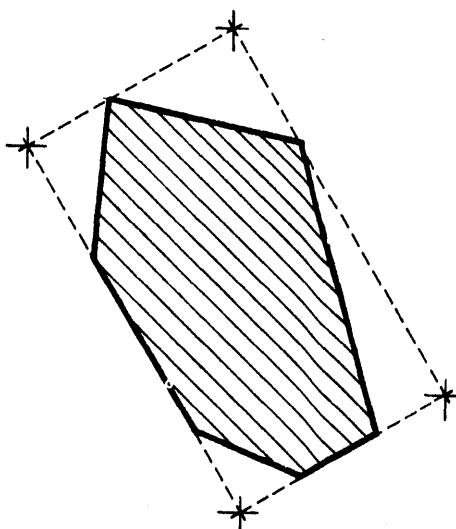
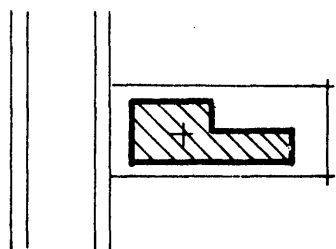
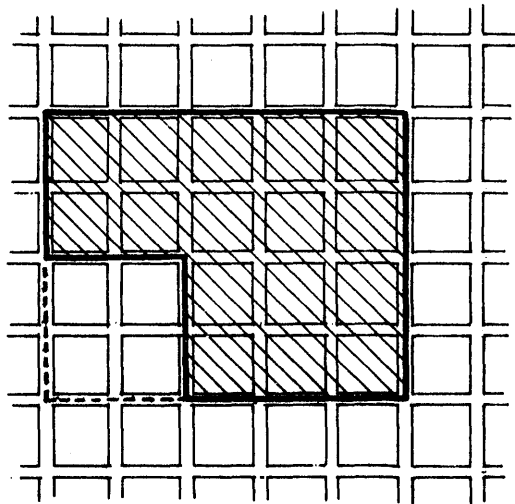
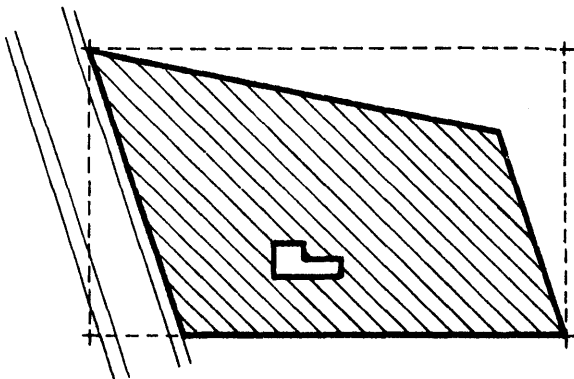
latitude &  
longitude  
coordinates

BUILDING, STRUCTURE or OBJECT  
on a site of more than  
one acre



latitude &  
longitude  
coordinates

BUILDING, STRUCTURE or OBJECT  
on a site of less than  
one acre



- a. For properties of an acre or more, a rectangle which includes the entire area to be recorded should be drawn on a map. Latitude and longitude for only four points--the corners of the rectangle--are needed. (See Illustration No. 1).
- b. For properties of less than one acre, only a single point locating the center of the property on the map is necessary.

C. PROPERTY PHOTOGRAPH FORM (Form 10-301)

Requirement: Photographs of professional quality must be submitted as a part of each nomination. The number of photographs should be determined by the requirement to provide adequate general pictorial representation of the property. One Property Photograph Form should be attached to each photograph submitted. One print of each photograph should be included and each print should be placed in a separate protective jacket. Prints should be black and white, maximum 8" by 10", minimum 4" by 5", medium weight, glossy finish, and unmounted.

Completing the Form:

1. NAME: Current common name of the property and any historical name(s).
2. LOCATION: Written geographic description of property location. Identify the township if applicable.
3. PHOTO REFERENCE: Identify the source and date for the photograph. Indicate the location of the negative.
4. IDENTIFICATION: Describe the view, direction, etc., of the individual photograph.

## **Appendix B**

### **Generalized Information System**

**Basic/360**

## GENERALIZED INFORMATION SYSTEM - Basic/360

GIS (Basic) provides the user with a generalized set of routines which allow data set creation, maintenance, query, and report formatting.

The GIS user describes his new or existing files in a procedure that does not involve detail programming. These file descriptions are done only once and are available to all subsequent users who require them. These descriptions after processing by the GIS program component enable the user to address the contents of his files by symbolic names. The size of each field, its units, relative location in the logical record, and other management parameters are contained in a dictionary and are usable in every procedure requiring them.

After defining the procedure requirements, the GIS (Basic) program component will (with diagnostic testing to ensure validity) compile executable program codes. This procedure can then be directly applied to files or data in the application. This procedure also may be stored for future use when called from the GIS (Basic) library by the procedures symbolic name.

The GIS (Basic) System is used in conjunction with OS/360. GIS (Basic) procedure can link to OS/360 Assembler Language routines referenced in the procedure specification. User routines written in PL/I or COBOL, can gain access (with some limitations) to the GIS (Basic) files.

GIS (Basic) is a structured file, information handling system designed for use where applications vary from specific data processing to the requirements of executive management information systems. The inclusion of additional routines and the providing of special reports are accomplished readily and the usual repetitive coding eliminated.

In summary the following are features found in the GIS (Basic) package:

- a. Program-assisted definition of simple and complex data set structures. All data locations are identified by user-assigned symbolic names.
- b. Simplifies data base creation by automatic field mapping and input/output control. Data insertion may be conditioned by logical tests and an audit trail is available.

- c. Permits multi-file retrieval of up to three independent data files (searched by a single query). The resulting "hits" in each file can be used to sequentially condition the next file's search or can be consolidated into a single report or output file.
- d. Allows multiple outputs (reports) in response to user selection logic.
- e. Performs algebraic computation, counts, and averages, as well as maximum-minimum detection.
- f. Maintains multi-field sort control for both data files and reports.
- g. Contains automatically formatted and customized report capabilities.
- h. Allows storage and recall of reusable task information which can be amended while in storage.
- i. Maintains file access control—128 levels (each) for retrieval and file maintenance.
- j. Performs automatic logging (recording) of error conditions; specifiable and default selection of alternative processing options in case of error.

An example of a query programmed in the language of the GIS (Basic) system follows:

#### GIS (Basic) Language

A hypothetical personnel file is used to identify all employees who worked in department 329 on or after January 1, 1962, and whose salary at the time exceeded \$1000 per month. A count or tally is made of the selected employees, and a list with their name, man number, home address, and current location code is requested. The procedure to accomplish this with GIS follows:

```

QUERY PERSONNEL
LOCATE JOB
WHEN DEPTNO EQ '329'
AND DATE GE '620101'
AND RATE GE '1000'
TALLY 1
LIST NAME, MANNO, HOMEADD, LOCATION
EXHAUST JOB OR 1
EXHAUST PERSONNEL
LIST 'COUNT OF RECORDS LISTED,' TALLY 1
END PROCEDURE

```

The word QUERY defines the procedure requirement and the file identified as the PERSONNEL file. The LOCATE JOB statement identifies the level of search for the procedure. The WHEN statement provides the search criteria and the records will be read but not truly located unless they contain a department number (DEPTNO) equal to 329, a date equal to or greater than January 1, 1962, and a monthly salary equal to or greater than \$1000.

This procedure specifies two actions to be performed, TALLY and LIST, for each qualifying record. Since duplicate records for an individual are possible, the EXHAUST JOB or 1 statement conditions only a single individual's record for selection. The second EXHAUST statement indicates the search should continue to the end of the personnel file.

Each individual's selected data fields are listed as the record is selected. A tally or count (as requested) is provided at the completion of the run.

#### SYSTEM/360 FORMATTED FILE SYSTEM (NIPS)

The System/360 Formatted File System (Naval Intelligence Processing System) was developed under government contract by the Federal Systems Division of IBM. NIPS is specifically designed to handle complex large volume batch query and file maintenance operations. Its processing capability includes many standard functions and utilities and operates under System/360/OS Primary Control Program (PCP) or Multiprogramming with a Fixed Number of Tasks (MFT II).

Full arithmetic and logical functions (including geographic searching techniques) are provided through high level programming languages for query use. A MACRO level language is available for file maintenance.

NIPS operating characteristics and languages make it desirable for users to have some programming experience, though this does not have to be extensive. Some of the features found in the system are:

- a. Supports Sequential Access Method (SAM) and Index Sequential Access Method (ISAM) files
- b. Supports a 2260 online terminal capability for retrieval

- c. Defines permanent file description tables and makes it available for use in all subsequent procedures
- c. Provides an unlimited number of files
- e. Provides an audit trail by using the POOL language
- f. Provides a flexible record format to allow for as many used as possible
- g. Uses boolean logic for record selection including geographic search operators and allowance for complex conditionals
- h. Provides multiple reports from one retrieval with formats defined by an output language processor or prestored for use
- i. Allows the system to support magnetic tape, disk, printer, CRT, and punched card devices
- j. Provides automatic file restructuring and prestored procedures with facilities provided for user code.

An example of a query programmed in the System/360 FFS language follows:

#### System/360 FFS (NIPS) Language

A source file is specified; a NIPS query extracts the desired records from it and constructs a reply. The reply can be ordered (sorted) and further processed by the system under the control of the output language used to produce the requested report format. A personnel file is interrogated

```
IF JOBCODE LT 21 AND YRSEXP
GT 10 AND (LOC EQ BOS OR LOC EQ NY).
SORT/1 NAME, MANNUM.
FURTHER IF SAL BT 500, 600 AND YRSEXP GT 15.
SORT/2 NAME, SAL, YRSEXP.
```

Records will be selected from the source file (Personnel File) which meets the following requirements:

- a. The job code is less than 21
- b. The years of experience are greater than 10
- c. The location is Boston or New York.

The reply is built with records selected from the file and is sorted using the fields NAME and MANNUM.

The FURTHER statement specifies that in addition to meeting all the previously stated search criteria, those records which also meet the additional criteria of salary between 500 and 600 and years of experience greater than 15 will be made into another answer set. A sort of this will follow using the fields NAME, SAL and YRSEXP as sort keys. Further processing of these replies by the output language processor would provide the output reports or files required.

## **Appendix C**

### **Advantages of COBOL and PL/I**

## COBOL

COBOL is a commercially-oriented programming language similar in form to English. It provides a number of features that reduce the cost of programming and extend the use of the language to new applications.

The COBOL Subroutine Library consists of subroutines which fall into the following major categories:

- a. Data Conversion routines
- b. Arithmetic verb routines
- c. Input/Output verb routines
- d. Other verb routines.

## PL/I

PL/I extends the range of applications that can be handled by a single high-level procedural language. In addition to covering problems similar to FORTRAN and COBOL, PL/I also covers problem areas beyond the scope of these languages, where past application efforts have required the use of ASSEMBLY language. The many features provided simplify programming of both commercial and scientific applications and assist the programmer in making efficient use of the supervisor facilities of OS/360. In terms of function, PL/I is the most complete high-level procedural language yet developed. Some of the features provided include:

- a. Many data types including fixed and variable length character and bit strings, floating decimal and binary data, fixed decimal and binary data and complex numeric data
- b. Complex data and arithmetic capability including expressions whose elements are scalars (individual numeric items), structures (collection of alphameric fields), and arrays (tables)
- c. Program segmentation capability providing for modular structure
- d. Automatic conversion and editing of data types where necessary
- e. Initialization of data elements and arrays
- f. Dynamic storage allocation under user control, permitting more efficient use of variable size data areas
- h. Stream input/output (extension of FORTRAN-like I/O)
- i. Record-oriented input/output (extension of COBOL-like I/O).

**Appendix D**

**Geometric Relationships for  
Retrieval of Geographic Information**

**by J. D. Jacobsen**

*Reported is an experimental technique that has been developed for retrieving, by geometrical means, information related to city maps.*

*This paper emphasizes the analysis needed to translate a retrieval query into relationships among points, vectors, and polygons. An illustration of the technique is given.*

## **INTERACTIVE GRAPHICS IN DATA PROCESSING Geometric relationships for retrieval of geographic information**

**by J. D. Jacobsen**

This paper discusses a package of subroutines, written in FORTRAN IV and executed under the IBM SYSTEM/360 Operating System (OS/360), that is designed to process geometric graphics data. The subroutines permit certain relationships to be determined between any two of the following geometric figures: points, vectors, convex or nonconvex polygons, and circles. The intended use of these programs is the retrieval of information indexed with geographic coordinate data.

After briefly mentioning the application for which the subroutines are primarily intended, the package design principles are discussed. The logic associated with several of the subroutines is explained in detail. The explanations are supplemented by an illustrative example of geographic information retrieval.

The subroutine package has application in the design of urban management information systems that use geographically oriented data. In systems of this type, a master file, or data base, is structured to include such file elements as streets, street intersection points, zoning districts (plus facts about them) in terms of a coordinate system. Geographic fact information may include, for example, block and parcel data, population and health statistics, traffic density, law enforcement, and planning and land use data.

Typically, system users—public works, public safety, transportation—seek information contained within an area of interest that is described to the system in coordinate form, as an input query. For example, an urban planner<sup>1</sup> might wish to select from a central data file all street intersection records (represented by a single pair of  $x$ - $y$  coordinates) falling within a specified area that has a non-convex polygon shape. Using this data base, such questions as the following could be answered:

- What are the property values, by type of land use, of parcels to be displaced by a proposed highway?
- What roads require resurfacing in a given geographic area?
- What is the school population within one-half mile of proposed sites for new school construction?
- How many police radio calls were received from a given area?

### **Retrieval objectives**

Experience in military information retrieval suggests the usefulness of geographic search operators. One such system, using an “overlapping polygon technique” wherein the geometric shape representing the area of interest is required to be convex, has proved to be adequate for the applications for which it was designed.

However, with the increasing interest in urban management and planning, it is desirable to include areas of interest that assume a nonconvex shape (police beats, school districts, proposed road-building, etc.). Thus, more general graphic processing techniques are needed. In response to this need, an experimental project was undertaken that produced the subroutines to be described.

These subroutines serve a retrieval function by determining whether a record from a data file belongs to a specified geographic area of interest. It should be understood that the subroutines do not contain a complete query processing capability, i.e., the ability to select or reject records by logically combining data fields specified by the input query. The only query parameters needed by the subroutines are the coordinates of the area of interest.

Since the areas of interest are generally small, the earth is assumed to be locally flat, and ideally the geographic portion of the file data record is oriented to a Cartesian coordinate system. Therefore, no provision need be made for the subroutines to transform from one coordinate system to another. If transformations are necessary, they are included in the user program. The Cartesian coordinate system allows the user to describe his area of interest by means of  $x$ - $y$  coordinate data. Moreover, he may enter polygon coordinates in either clockwise or counter-clockwise fashion, although he must enter them in order.

Because programming takes the form of subroutines, array names and coordinate counts are transmitted through an argument list in the calling sequence. Also appearing in this list is a parameter that serves as an output status code. The parameter is assigned a

value by the subroutine and represents the relationship existing between the file element and the query polygon. This code can then be interpreted by the calling program.

For example, an urban planner might wish to select all street intersection records from a central data file (geographically represented by a single pair of  $x$ - $y$  coordinates) falling within a specified area of interest that graphically assumes the shape of a nonconvex polygon. The executed subroutine is named the point-polygon subroutine (POINTP). Its function is to determine whether a single point lies inside, outside, on a vertex, or on a polygon side. The determined status is returned to the calling program by assigning to a calling sequence parameter the value 1, 2, 3, or 4, as shown in Figure 1. In this manner, any status determined by the subroutine can be interpreted as an inclusion or a rejection by the calling program.

### Analysis and design

The following is a discussion of the analysis used in designing some of the subroutines.<sup>2,3</sup> Presented is a solution to the "point nonconvex-polygon problem" and the resulting point-polygon subroutine (POINTP). Also outlined is the basic mathematics involved in determining the required relationships between two straight-line vectors, which result in the vector-vector subroutine (VECTV). Finally, a practical application of these two subroutines is presented in order to explain the vector-polygon subroutine (VECTP), which recognizes various relationships between a vector and a polygon.

A technique for determining whether a single point lies inside or outside a polygon is explained as follows. Construct a point  $P$  and a polygon as shown in Figure 2. Extend a line from the point indefinitely in any direction. If this line intersects an odd number of polygon sides, the point is inside the polygon. If the line intersects an even number of polygon sides, the point is outside the polygon. This technique is implemented in the POINTP subroutine by performing an axis translation and by letting point  $P$  be the origin of the translated coordinate system. The positive  $y$  axis in Figure 3 becomes the extended line.

Counting the number of polygon sides crossing the positive  $y$  axis is done by simple comparisons of the signs of the polygon-side end-point coordinates. Coordinates of the two end points falling in adjacent quadrants above the  $x$  axis indicate a crossing of the positive  $y$  axis as shown in Figure 4A. The positive  $y$  axis is a convenient choice because one of the cases that can arise is where polygon side coordinates lie in opposite quadrants. In that case, the  $y$  intercept

$$b = y_1 - \left( \frac{y_2 - y_1}{x_2 - x_1} \right) x_1$$

must be computed to determine whether the positive  $y$  or negative  $y$  axis is crossed as shown in Figure 4B.

Figure 1 Point-polygon relationships

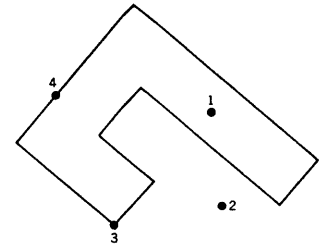


Figure 2 Determining an interior or exterior point

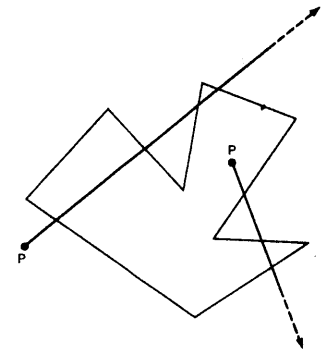


Figure 3 POINTP subroutine geometry

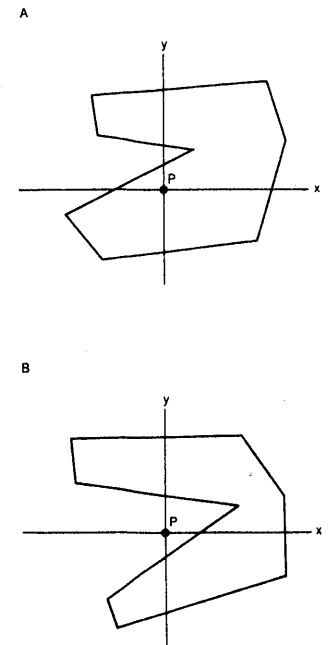


Figure 4 Counting polygon-side crossings

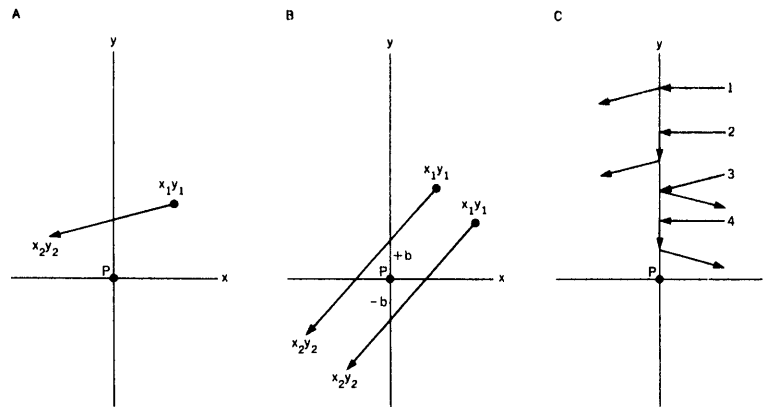


Figure 5 Vector-vector relationships

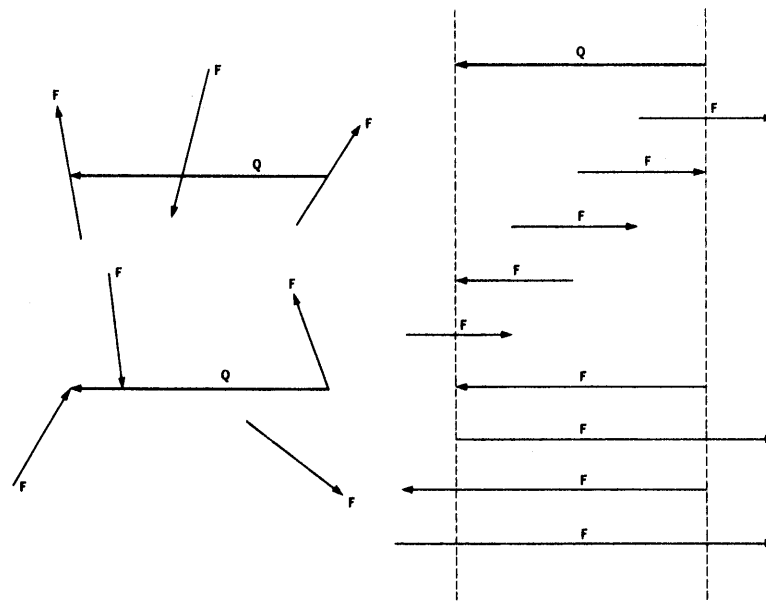


Figure 4C illustrates the remaining axis-intercept conditions that must be recognized by the subroutine POINTP. Vectors 1 and 2 intersect the positive  $y$  axis, whereas vectors 3 and 4 do not. Furthermore, if the polygon vector intersects the origin  $P$ , the point lies on the vector. If the vector head coincides with the origin, the point is at the vertex.

A subroutine is needed to determine the various relationships between vectors and polygons. The vector-vector subroutine (VECTV) serves this purpose by recognizing relationships between two vectors which, in the practical case, would be a street from a data file ( $F$ ) and a polygon vector (query vector  $Q$ ).

From Figure 5 it can be seen that the conditions that must be recognized basically involve intersections, superimposition, and end-to-end contact. (It is understood that the **Q** and **F** vectors could be directed oppositely to those shown in the figure.) The logic of **VECTV** takes advantage of the fact that in many cases there is no contact between the file vector and a vector from the query polygon. Therefore, intersection, parallelism, colinearity, and superimposition are looked for in that order. Since we are interested in the intersection of two line segments, we can represent them in parametric form and solve the resulting equations simultaneously.<sup>4</sup> Thus,

$$\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} x_2 & x_1 \\ y_2 & y_1 \end{bmatrix} \begin{bmatrix} t \\ 1-t \end{bmatrix} \quad \text{where } 0 \leq t \leq 1$$

$$\begin{bmatrix} w \\ z \end{bmatrix} = \begin{bmatrix} u_2 & u_1 \\ v_2 & v_1 \end{bmatrix} \begin{bmatrix} p \\ 1-p \end{bmatrix} \quad \text{where } 0 \leq p \leq 1$$

For intersection to occur, there must exist a  $t_0$  and  $p_0$  such that  $0 \leq (t_0, p_0) \leq 1$ , and, when these values are substituted into the above,

$$\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} w \\ z \end{bmatrix}$$

Therefore,

$$\begin{bmatrix} t_0 \\ p_0 \end{bmatrix} = \begin{bmatrix} x_2 - x_1 & u_1 - u_2 \\ y_2 - y_1 & v_1 - v_2 \end{bmatrix}^{-1} \begin{bmatrix} u_1 - x_1 \\ v_1 - y_1 \end{bmatrix}$$

whenever the inverse exists.

Simplifying the above,

$$\begin{bmatrix} t_0 \\ p_0 \end{bmatrix} = \begin{bmatrix} a & b \\ c & d \end{bmatrix}^{-1} \begin{bmatrix} e \\ f \end{bmatrix}$$

so that the problem of solving for  $t_0, p_0$  reduces to  $D = ad - cb$ , where  $D$  is the determinant. Finally,

$$t_0 = \frac{de - bf}{D}$$

and

$$p_0 = \frac{af - ce}{D}$$

Figure 6 graphically illustrates the effect of the calculations  $t_0$  and  $p_0$ . If the determinant  $D$  equals zero, the two vectors are parallel.

The next step, then, is to determine if the vectors are colinear, and if so, whether they are superimposed. To test for colinearity, a vector cross product is formed as follows:

$$VCP = (y_1 - v_1)(u_2 - u_1) - (x_1 - u_1)(v_2 - v_1)$$

If  $VCP = 0$ , then the vectors are colinear; if  $VCP \neq 0$ , then the vectors are not colinear. Figure 7A illustrates the case where two vectors are not colinear and Figure 7B where they are colinear.

Figure 6 Graphic representation of  $t_0$  and  $p_0$

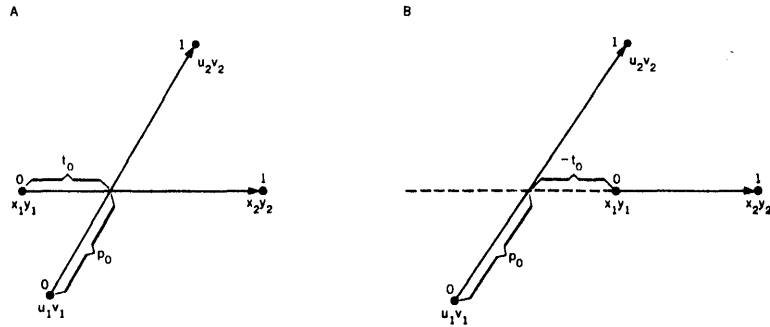
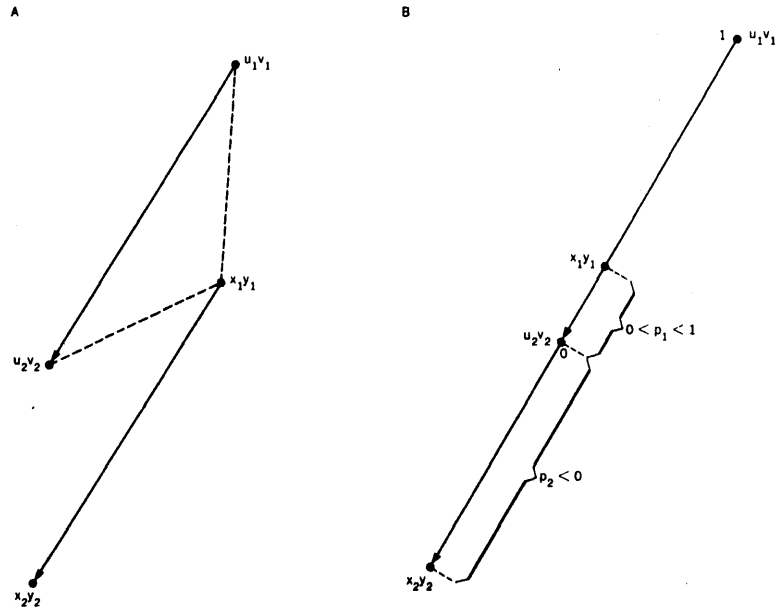


Figure 7 Vector colinearity test



Where the vectors are colinear, a test is made for superimposition by solving for  $p_1$  and  $p_2$ , the parametrizations of  $(x_1, y_1)$  and  $(x_2, y_2)$  in terms of  $(u_1, v_1)$  and  $(u_2, v_2)$ , respectively.<sup>2.5</sup> Thus,

$$(x_i, y_i) = p_i(u_1, v_1) + (1 - p_i)(u_2, v_2) \quad \text{for } i = 1, 2$$

If  $u_1 \neq u_2$ , as shown in Figure 7B, then

$$p_i = \frac{x_i - u_2}{u_1 - u_2} \quad \text{for } i = 1, 2$$

Otherwise,  $v_1 \neq v_2$ , and

$$p_i = \frac{y_i - v_2}{v_1 - v_2} \quad \text{for } i = 1, 2$$

Both  $p_1$  and  $p_2$  must be evaluated to distinguish between the nine cases illustrated in Figure 5. Figure 7B shows superimposition, since  $0 < p_1 < 1$ . For superimposition to occur,

$$0 < [p_1 \cup p_2 \cup (p_1 \cap p_2)] < 1$$

Once it is established that there is some contact between the two vectors, a coordinate list is set up. This list is a four-word array whose name and number of entries appear in the **VECTV** calling sequence and contains either the coordinates of intersection, the coordinates involved in superimposition, or the coordinates of end-to-end contact.

The previously described subroutines **POINTP** (point-polygon) and **VECTV** (vector-vector) are now used to recognize various relationships existing between vectors and polygons. A vector may partially be included in a polygon under three conditions: (1) at least one vector point must be inside the polygon (as determined by **POINTP**), or (2) both points must be inside and the vector intersects the polygon, or (3) both points are outside the polygon and the vector intersects the polygon (as determined by **VECTV**). If both points are inside the polygon and the vector does not intersect any polygon sides, then the vector is totally included in the polygon. (Vector-polygon relationships are illustrated in Figure 8.)

The subroutine logic is organized as follows. First, both vector end points are investigated to determine the combination of point-polygon relationships that exists. These relationships are shown systematically in the point-polygon status matrix in Table 1. The status matrix elements are pointers to segments of subroutine logic executed after the polygon is processed against the vector, which is done to look for intersections, superimpositions, etc.

Thus, when the relationship of one vector endpoint with respect to the polygon is established, we can refer to the **POINTP** output that reflects this relationship as  $i$  and similarly for the other endpoint  $j$ . Then, the point-polygon status matrix element  $(i, j)$  in Table 1 is the program pointer assigned. For example, the element 9 [matrix element  $(i, j) = (2, 2)$ ] in the status matrix serves as a pointer to the subroutine segment to be executed when both vector end points are found to be outside the polygon. The segment is executed after processing the polygon against the vector.

Figure 8 Vector-polygon relationships

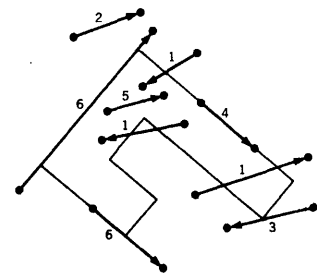


Table 1 Point-polygon status matrix

POINTP Output ( $i$ )	POINTP Output ( $j$ )			
	1 In	2 Out	3 On vertex	4 On line
1 In	1		4	5
2 Out		9	12	15
3 On vertex	4	12	16	20
4 On line	5	15	20	25

Figure 9 Relating a vector to a polygon

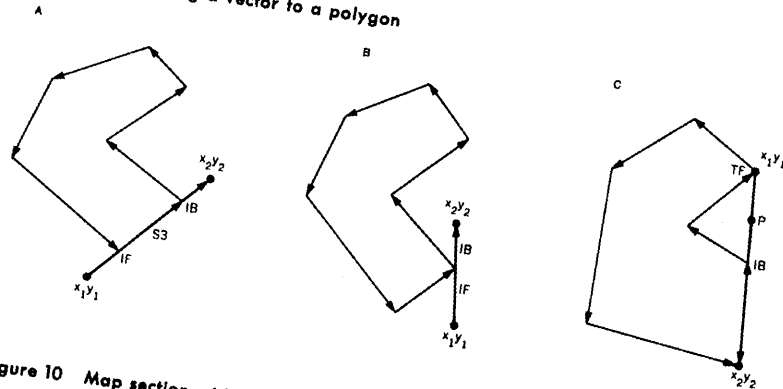
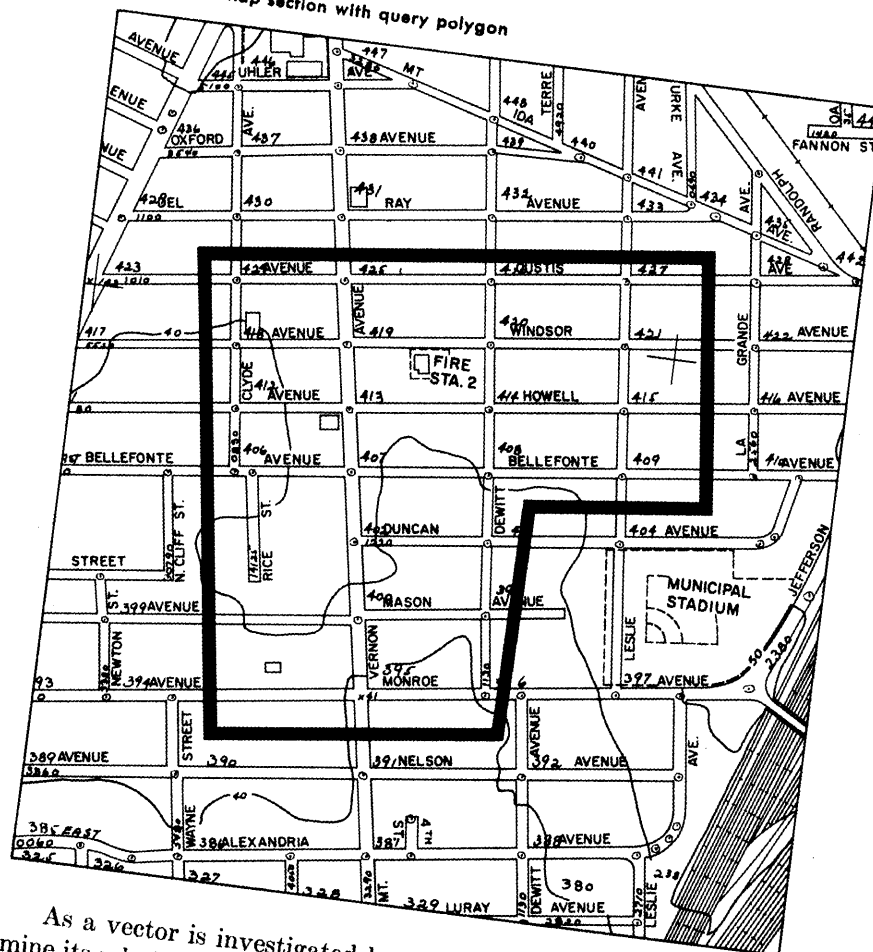


Figure 10 Map section with query polygon



As a vector is investigated by the VECTV subroutine to determine its relationship to each polygon vector, the VECTP subroutine records the VECTV output (transmitted through the calling sequence output parameter) by assigning a truth value to a corresponding FORTRAN IV logical variable. These logical variables are given in Table 2, and some of them are shown in Figure 10. In Table 2, for example, if a vector intersects a polygon vector at its initial point, a truth value is assigned to the logical variable IB.

Table 2 FORTRAN IV logical variables for a vector and a polygon vector

<i>Polygon vector</i>	<i>Vector</i>				
	<i>Intersects</i>	<i>Touches</i>	<i>Wholly contained in polygon vector</i>	<i>Extends beyond either initial or terminal point of polygon vector</i>	<i>Extends beyond both initial and termi- nal points of poly- gon vector</i>
Between initial and terminal points	IM	TM			
At initial point	IB	TB			
At terminal point	IF	TF			
Superimposition			S1	S2	S3

Whenever an intersection is encountered, processing terminates because the vector lies partially inside the polygon. If no intersections are found and if polygon processing ends, then the subroutine segment represented by the appropriate status matrix element  $(i, j)$  is selected. Each subroutine segment is designed to interpret the results of the polygon processing phase by logically interrogating and combining the results to produce the types of vector-polygon relations required. For example, Figure 9 shows three of a number of possible relations that might exist between a vector and a polygon. In Figures 9A and 9B, the POINTP subroutine determines that both vector end points are outside the polygon. In these cases, the status matrix indices  $(i, j)$  would have the values  $(2, 2)$ . Processing the polygon against the vector yields no intersections. However, the logical variables IF, S3, and IB are "true" for Figure 9A, and IF and IB are "true" for Figure 9B.

The status matrix indices  $(2, 2)$  are used to select subroutine segment 9, the logic of which is as follows. If S3 is "true," the subroutine output parameter reflecting the vector-polygon relationship is assigned the value 6, as shown in Figure 8, and control is returned to the user program. Otherwise, if IB is "true," the output parameter is assigned the value 3, indicated in Figure 8, and control returns to the user program. If neither S3 nor IB is true, then there is no contact between the vector and the polygon. In this case, the value 2 from Figure 8 is assigned to the output parameter, and control returns to the user program.

If both of the vector end points coincide with the vertices of the polygon, as shown in Figure 9C, then a different segment of subroutine logic is executed (number 16 in the status matrix in Table 1) providing no intersections were encountered in processing the vector against the polygon. During this processing, the coordinates of the two points labeled IB and TF are placed in a list. Thus, inclusion or superimposition is determined by (1) averaging the

coordinates of IB and TF and (2) using the point-polygon program to determine whether the average (point  $P$ ) is inside or outside the polygon.

### **Geographic information retrieval**

Since the motivation for our work is to develop methods for processing geographically oriented data, a brief illustration is given here. (Other applications and subroutine testing are discussed in greater detail elsewhere.<sup>6</sup>) The example is a public-works query for which a listing is produced of streets within an area of a city bounded by a polygon. The data base consists of a street file and a land-parcel file in the city of Alexandria, Virginia. This data base is linked to city maps through a digitizing and file expanding process. An  $x$ - $y$  coordinate reader was used to digitize the coordinates that identify streets and to initiate punching the coordinates into cards. The cards were used to insert the coordinates into the street file. Data files are stored on an IBM 2314 direct-access storage device. File manipulation is effected through IBM 1050 remote terminals and SYSTEM/360 operating under OS/360 and a generalized file maintenance, retrieval, and formatting program called FASTER.

A digital representation of the polygon area of interest enters the computer via the remote terminal and an  $x$ - $y$  digitizer. A number that represents a preprogrammed query type (creating a listing of streets, in our example) is also entered by the digitizer through the 1050. (Query input data are displayed on a typewriter terminal, while the output is produced by both typewriter and an IBM 1403 printer.)

Test results demonstrate the feasibility of applying the geometric graphic subroutines to geographic information retrieval. Figure 10, in our example, shows the query area superimposed on a section of the Alexandria city map, and Figure 11 is the output street listing corresponding to our example query polygon. Street identifications are given by numbers rather than by street names. For example, the designation S-3290-1600 refers to street file S, Mt. Vernon Avenue (3290), and to the lowest street address (1600) in the block desired.

### **Concluding remarks**

This discussion has sought to strike a balance between comprehensiveness and detail in the exposition of mathematical and programming methods for processing geometric graphics data. Therefore, it seemed necessary to omit discussions of several techniques and subroutines that have also been worked out.

Work described in this paper could benefit those engaged in or contemplating the design of urban management information systems geared to a geographically oriented data base. The experimental programming system described in this paper is evolving to meet and anticipate requirements of those seeking urban improve-

Figure 11 Street listing for query polygon

CITY OF ALEXANDRIA PUBLIC WORKS-TRAFFIC AREA															PAGE 0001			
STREET ID	PLT CRST	YR CNS	LT YR	LAST RESURF	TYPE OF RESURFNG	RTG WIDTH	BY WIDTH	WIDTH PAVMT	WIDTH RCHG	LGTH BLCK	SURFACE TYPE	SURF THICK	SURF COND	PAST TYPE	BASE THICK	BASE COND	MEDIAN	TYPE
S-0270-0100	CITY	38	84	-		40		20	24	877	PLANT MIX	2	GOOD	GRAVEL	8	GOOD	NO	MEDIAN
S-0270-0150	UNK			-							UNPAVED		N/A	N/A		N/A	NO	MEDIAN
S-0270-0200	CITY	33	72	-		40		20	24	520	UNPAVED	1	FAIR	GRAVEL	8	FAIR	NO	MEDIAN
S-0270-0300	CITY	33	72	-		40		20	24	516	UNPAVED	1	FAIR	GRAVEL	8	FAIR	NO	MEDIAN
S-3170-0300	CITY	49	84	-		50		36	40	482	PLANT MIX	2	GOOD	PORTLD CEMENT	8	GOOD	NO	MEDIAN
S-3290-1600	CITY	29	84	-		60		36	40	290	PLANT MIX	2	GOOD	PORTLD CEMENT	8	GOOD	NO	MEDIAN
S-3290-1700	CITY	29	84	-		60		36	40	270	PLANT MIX	2	GOOD	PORTLD CEMENT	8	GOOD	NO	MEDIAN
S-3290-1800	CITY	29	84	-		60		36	40	270	PLANT MIX	2	FAIR	PORTLD CEMENT	8	GOOD	NO	MEDIAN
S-3290-1900	CITY	29	84	-		60		36	40	230	PLANT MIX	2	GOOD	PORTLD CEMENT	8	GOOD	NO	MEDIAN
S-3290-2000	CITY	29	84	-		60		36	40	230	PLANT MIX	2	GOOD	PORTLD CEMENT	8	GOOD	NO	MEDIAN
S-3290-2100	CITY	29	84	-		60		36	40	230	PLANT MIX	2	GOOD	PORTLD CEMENT	8	GOOD	NO	MEDIAN
S-4125-0000	UNK			-							UNPAVED		N/A	N/A		N/A	NO	MEDIAN
S-5520-0100	UNK		84	-		40		20	24	403	PLANT MIX	2	GOOD	PORTLD CEMENT	8	GOOD	NO	MEDIAN
S-5520-0200	CITY	36	72	-		40		20	24	525	UNPAVED	1	FAIR	GRAVEL	8	FAIR	NO	MEDIAN
S-5520-0300	CITY	36	72	-		40		20	24	516	UNPAVED	1	FAIR	GRAVEL	8	FAIR	NO	MEDIAN

ments by applying systems engineering techniques to management, planning, and administrative functions.

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